NATIONAL ACID PRECIPITATION ASSESSMENT PLAN

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TVA
Tennessee Valley Authority

NATIONAL ACID PRECIPITATION ASSESSMENT PLAN

PREPARED BY

THE INTERAGENCY TASK FORCE ON ACID PRECIPITATION

Participating Federal Departments and Agencies:

Department of Agriculture (DOA), Joint Chair

Environmental Protection Agency (EPA), Joint Chair

National Oceanic and Atmospheric Administration (NOAA), Joint Chair

Department of the Interior (DOI)

Department of Health and Human Services (HHS)

Department of Commerce (DOC)

Department of Energy (DOE)

Department of State (DOS)

National Aeronautics and Space Administration (NASA)

Council on Environmental Quality (CEQ)

National Science Foundation (NSF)

Tennessee Valley Authority (TVA)

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EXECUTIVE SUMMARY

The Acid Precipitation Act of 1980 (Title VII of The Energy Security Act of 1980 - P.L. 96-294) established the Interagency Task Force on Acid Precipitation to develop and implement a comprehensive National Acid Precipitation Assessment Program. The Act requires the Task Force to produce a National Plan for the ten-year research program; this document is that Plan. The Plan is written for a nontechnical audience and provides a brief overview of the issue and broad outline of the National Program. This overview document is supported by technical operating plans for managing the federal research program.

The purpose of the National Acid Precipitation Assessment Program is to increase our understanding of the causes and effects of acid precipitation. The National Program includes research, monitoring and assessment activities that emphasize the timely development of a firmer scientific basis for decision making. This program of policy-oriented research issues Annual Reports describing research progress and the current state of knowledge about acid precipitation and its implications. The first Annual Report to the President and the Congress was issued in January 1982.

The National Program will use a general strategy that includes:

- Building upon previous efforts to develop a federal acid rain program. The former Acid Rain Coordinating Committee (ARCC) has been reconstituted to form the statutory Task Force; the ARCC draft plan was refined and has served as a foundation for developing the current plan.

- Using existing scientific knowledge for timely assessments and, where appropriate, policy recommendations. Currently available data and information from the U.S. and other nations will be critically analyzed and applied where possible.

- Conducting research to develop more knowledge. The emphasis in the proposed research will be on activities that contribute most effectively to establishing a firmer scientific basis for decision making.

- Establishing a long-term National Trends Network (NTN). The development and maintenance of a well-designed acid precipitation (wet and dry) monitoring network is essential for documenting and understanding acid precipitation and its effects. Existing monitoring efforts, such as those of the National Atmospheric Deposition Program (NADP), will be incorporated into the NTN.

- Evaluating information and the policy implications. Information generated by the National Acid Precipitation Assessment Program and other research efforts in this country and abroad, are expected to contribute significantly to our knowledge. The information produced will be synthesized periodically, subjected to scientific peer review, published and interpreted to guide decisions on future research. The Task Force will report annually to the President and Congress on the research program's progress and implications of the existing knowledge.

The Task Force will work with all those concerned to ensure that the federal activities are conducted as part of a comprehensive and well coordinated National Program. The National Program will utilize the expertise available in federal and state agencies, universities, industry, private contractors, and research institutions.

The Plan

The National Acid Precipitation Assessment Plan has five parts. Part I is an introduction that describes the authorizing legislation and outlines the organization of the Plan itself. A history of previous federal planning efforts in the area of acid precipitation is given and brief descriptions of the current acid rain research programs of the major federal agencies as well as examples of nonfederal activities are provided.

Part II of the Plan presents a general overview of current understanding of the phenomenon and consequences of acid rain. Key technical terms are defined and a brief overview of the existing state of knowledge about acid precipitation and its effects is presented. Subjects discussed include: evidence of trends in rainfall acidity; possible sources of acid precipitation; atmospheric chemistry and transport; monitoring of acid deposition; the effects of acid precipitation; the relationship of acid precipitation to human health; and control technologies and mitigation of impacts.

Part III of the Plan identifies and discusses the information needed to increase our understanding of the phenomenon and consequences of acid precipitation. Answers are needed to many of these questions in order to enhance our ability to make sound energy, environmental, economic, and resource policy decisions. The information needs are divided into nine research categories: A) natural sources; B) man-made sources; C) atmospheric processes; D) deposition monitoring; E) aquatic impacts; F) terrestrial impacts; G) effects on materials and cultural resources; H) control technologies; and I) assessment and policy analysis. Possible indirect effects on human health are addressed in both categories E) and F).

Part IV presents the research proposed to address the information needs identified in Part III. Research tasks are described for each of the nine research categories. Coordinating agencies are designated for each research category and for each specific research task the following is indicated: its relative priority; the directly participating and indirectly contributing agencies; and the scheduling and duration of the proposed work. A table summarizing all the proposed research in the National Program is presented in Appendix A.

The management and coordination of the Program are described in Part V. A general strategy for the Program is presented and the organization and responsibilities of the Task Force and its constituents are described. The interagency budget process, production of the Annual Report, special assessment documents, coordination with nonfederal activities, and international cooperation are also discussed.

Proposed Research

Research is proposed in nine basic categories (see A through I, Part IV), where more information about acid precipitation is needed. The research tasks

described each focus on a specific area and generally involve the coordinated participation of several agencies. The number and extent of the proposed research tasks eventually carried out will depend on the resources and assessment of information needs in future years.

Each research task has been assigned one of three priority levels. Priority 1 denotes the most urgently needed research that offers the opportunity for relatively rapid generation of crucial information. Tasks of slightly less urgency are given a priority 2, and priority 3 indicates important research but where the need for results is least urgent. With funding available for FY 1982, the first full year of the mandated research program, work has begun on most priority 1 and 2 tasks and some priority 3 tasks.

Specific tasks, the priorities assigned, participating agencies, and research durations are summarized in Appendix A of this Plan.

Organization and Implementation

The Interagency Task Force on Acid Precipitation is jointly chaired by the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA). The other participating federal entities are: the Departments of the Interior (DOI), Health and Human Services (HHS), Commerce (DOC), Energy (DOE), State (DOS); the National Aeronautics and Space Administration (NASA); the Council on Environmental Quality (CEQ); the National Science Foundation (NSF); and the Tennessee Valley Authority (TVA). The Task Force also includes four Presidential appointees and the Directors of the Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and the Pacific Northwest National Laboratory.

The main responsibilities of the Task Force are to:

- Develop and update the National Acid Precipitation Assessment Plan;
- Oversee and implement a ten-year comprehensive research program that coordinates and focuses the acid rain activities of the federal agencies;
- Maintain an inventory of federally-funded acid precipitation research projects;
- Develop an annual interagency budget for the federal program;
- Provide Annual Reports on the program's progress and implications of the existing knowledge;
- Provide productive interaction between the federal program and private sector, academic, state and local governmental, and international activities; and
- Obtain nonfederal input to the planning, review, and program activities.

The Task Force meets at least three times a year to develop budgets, establish objectives, set priorities, approve plans and reports, and conduct program

reviews. Federal acid precipitation research and assessment activities are coordinated and integrated by the Task Force to form a cohesive national program.

Individual agencies' projects are carried out in the context of the National Program defined by the current ten-year Plan (as updated and revised by the Annual Reports) and with oversight by the Task Force. Technical Task Groups for each of the nine research categories oversee and facilitate detailed planning of activities in their assigned areas. A Research Coordination Council integrates the outputs of the Task Groups as well as develops and updates the detailed operating research plan for the National Program. A Program Coordination Office serves as the focal point for planning and coordinating the interagency federal effort. The Office is managed by the Task Force's Executive Director and is responsible for disseminating information and providing liaison with nonfederal activities, other nations, and the public.

The role of the Task Force in planning the interagency budget for the National Program is an important aspect of the federal effort. The Task Force develops a coordinated interagency budget for the National Acid Precipitation Assessment Program. By working together through the Task Force, the agencies have established a research program that focuses on addressing national needs. The strong interagency planning process eliminates undesirable duplication and avoids crucial omissions in the National Program.

The Task Force sets the research goals for the National Acid Precipitation Assessment Program, identifies the projects needed to meet those goals, and decides which agencies are best suited to conduct the necessary work. The result is a comprehensive program of interlocking projects, with each agency contributing to specific aspects of the overall national effort.

Relationship to Other Activities

The Task Force has no regulatory responsibilities but periodically can make recommendations to assist in determining national policies related to acid precipitation. The role of the Task Force is to conduct a vigorous ongoing research and monitoring program, and provide policy-makers with assessments of the state and implications of information produced by the program.

The Task Force maintains a Task Group on international activities. This group is coordinated by the Department of State and will assist the Task Force in ensuring that the U.S. National Acid Precipitation Assessment Program effectively cooperates with relevant international activities.

I. INTRODUCTION

A. Authorizing Legislation

The "Acid Precipitation Act of 1980," passed by Congress as Title VII of the "Energy Security Act of 1980" (PL 96-294), was signed into law by the President on June 30, 1980. The purposes of the Act are:

(1) To identify the causes and sources of acid precipitation;

(2) To evaluate the environmental, social, and economic effects of acid precipitation; and

(3) Based on the results of the research program established by this subtitle and to the extent consistent with existing law, to take action to the extent necessary and practicable (a) to limit or eliminate the identified sources of acid precipitation, and (b) to remedy or otherwise ameliorate the harmful effects which may result from acid precipitation.

The Congress stated that the term "acid precipitation" implies "both wet and dry deposition from the atmosphere of acid chemical compounds." That broad definition of the term applies throughout this document.

The Act calls for a comprehensive ten-year program and establishes an Interagency Task Force on Acid Precipitation to plan and implement the mandated national effort. This Task Force was charged with developing a comprehensive plan for the program and presenting a draft of the plan to Congress within six months after the bill was signed into law. A sixty-day public comment period followed submission of the draft to Congress; the Task Force has revised this plan and is submitting it in final form to the Congress and the President for promulgation. A more complete description of how the National Plan was developed, extensively reviewed and revised, is included in Section C of this Introduction.

The Act requires that the Plan include comprehensive programs for:

(1) Identifying the sources of atmospheric emissions contributing to acid precipitation;

(2) Establishing and operating a nationwide, long-term monitoring network to detect and measure levels of acid precipitation;

(3) Conducting research in atmospheric physics and chemistry to facilitate understanding of the processes by which substances emitted into the atmosphere are transformed into acid precipitation;

(4) Developing and specifying the application of atmospheric transport models for use in the prediction of long-range transport of substances causing acid precipitation;

(5) Defining geographic areas of impact through deposition monitoring, and identifying sensitive areas and areas at risk;

(6) Broadening of impact data bases by consolidating existing data on water and soil chemistry and by conducting trend analyses;

(7) Developing dose-response functions with respect to soils, soil organisms, aquatic and amphibious organisms, crop plants, and forest plants;

(8) Establishing and carrying out system studies with respect to plant physiology, aquatic ecosystems, soil chemistry systems, soil microbial systems, and forest ecosystems;

(9) Assessing the economic effects of (a) acid precipitation on crops, forests, fisheries, and recreational and aesthetic resources and structures, and (b) alternative technologies to remedy or otherwise ameliorate any harmful effects that may result from acid precipitation;

(10) Documenting current federal activities related to research on acid precipitation and ensuring that such activities are coordinated to prevent needless duplication and waste of financial and technical resources;

(11) Effecting cooperation in current and planned acid precipitation research and development programs between affected and contributing states and with other sovereign nations having a commonality of interest; and

(12) Analyzing existing information on acid precipitation as a means to formulate and to present periodic recommendations to the Congress and the concerned agencies on actions that can be taken by these bodies to alleviate acid precipitation and its effects.

B. Organization of the Plan

The National Acid Precipitation Assessment Plan, prepared by the Task Force to fulfill its responsibilities under the Acid Precipitation Act of 1980, includes provisions to deal with all the legislatively mandated elements. In addition, this Plan provides general descriptions of the phenomenon and possible effects of acid precipitation, as well as a basic rationale for the research proposed. The Plan is written for a nontechnical audience and is intended to provide a broad overview of the Program. More detailed operating plans are used by the Task Force to supplement this general document.

Section C and parts of Sections D and E of this Introduction give a brief description of previous federal efforts to coordinate acid precipitation research and to develop interagency plans. Also presented is information on the FY 1982 acid precipitation programs of the individual agencies with major acid rain efforts.

Part II of this Plan is an overview of the phenomenon, effects, and possible strategies for management of acid precipitation. Briefly described are: the natural and man-made sources of acid deposition; the chemical transformation, transport, and deposition of such substances by the atmosphere; the monitoring of atmospheric deposition; the effects of acid deposition, including its potential consequences for human health; and the control technology and mitigation options. Part II also contains definitions of terms used in connection with acid precipitation and current evidence of changes in long-term deposition acidity.

Part III outlines the major gaps in our knowledge of the phenomenon and consequences associated with acid precipitation. It provides a guide to crucial information needs in nine specific areas: natural sources; man-made sources; atmospheric processes; deposition monitoring; aquatic impacts; terrestrial impacts; effects on materials and cultural resources; control technology; and assessment and policy analysis (See A through I, Part III). Improved understanding in all of these areas is needed for the formulation of sound energy production, resource management, and environmental protection policies. The Task Force's First Annual Report (January, 1982) provides a synopsis of how these information needs and the research tasks in Part IV directly address key policy concerns.

Part IV describes proposed research tasks considered essential for filling the information needs described in Part III. Each research task is described briefly, together with its assigned priority, the directly participating and indirectly contributing agencies, and the starting and duration time for the research. The research described in detail in Part IV is summarized in tabular form in Appendix A.

Part V describes the Task Force, its organization, and its strategy for implementing a coherent program of policy-oriented research and analyses. Plans are outlined for coordinating federal agency efforts, and for cooperating and communicating with relevant nonfederal (state, private sector, etc.) and international research and monitoring activities. Finally, a dynamic process is presented for periodic reassessment of currently available knowledge and its policy implications.

This Plan was written for use by four major groups: (1) the President and the Congress; (2) leaders of local, state, and federal agencies, industry and environmental organizations; (3) members of the scientific community; and (4) the general public. In addition to this general National Plan, the Research Coordination Council maintains a more detailed operating research plan for managing the program. The operating plan contains specific information on the individual projects including the technical and administrative aspects.

C. Development of the Plan

In accordance with the Act (PL 96-294), a draft National Acid Precipitation Assessment Plan was submitted to Congress in January 1981. Two thousand copies were distributed and comments were received from state and local governments, universities, environmental groups, various industries, the general public, and other nations. The many valuable suggestions of these groups were given careful consideration in the revision of the draft National Plan.

In addition to receiving public comments, the Task Force took other steps to ensure adequate review of the draft National Plan. A joint U.S. National Academy of Sciences and Royal Society of Canada Scientific Committee on Acid Precipitation reviewed the draft plan in March 1981. This bilateral group of 14 prominent scientists provided the Task Force with a very useful critique of the draft document.

In April 1981, the Task Force sponsored a workshop of nonfederal experts to review critically the plan and provide suggestions on how the federal efforts could best be coordinated with the state and private sector activities. The

workshop involved a balanced group of 27 participants with diverse expertise and affiliations, including state governments, environmental groups, and various industries. The participants determined the draft was, in general, an excellent beginning and they suggested many valuable improvements.

In June 1981, a delegation of Canadians representing various federal and provincial research groups met with Task Force representatives to discuss the draft plan. Information was exchanged on the two nations' acid rain research efforts. The participants agreed to establish ongoing mechanisms for coordinating research and to continue collaboration on monitoring activities.

The Task Force has used the recommendations from these diverse sources to revise the draft plan and develop this current version of the National Acid Precipitation Assessment Plan. The Task Force's Annual Reports will provide a mechanism for periodically updating this National Plan.

Task Force efforts in planning and implementing a National Acid Precipitation Assessment Program have been built upon previous federal activities. Prior to the passage of the Acid Precipitation Act of 1980, an Executive Branch effort to develop a coordinated federal program was underway. The Acid Rain Coordinating Committee (ARCC) was established in response to the President's Environmental Message of August 2, 1979. However, in October 1980, the ARCC was reconstituted to form the statutory Interagency Task Force on Acid Precipitation. The Task Force includes the original ARCC members plus some additional representatives required by the law (PL 96-294).

The ARCC prepared a draft "Federal Acid Rain Assessment Plan" in September 1980 and submitted it for review by a broad spectrum of individuals in academia, private industry, state and local governments, and federal agencies. Although some aspects of the ARCC draft plan were utilized in the preparation of the current plan, extensive revisions and additions are included in response to the legislation, critiques of the ARCC draft, and the subsequent Task Force activities described above.

The earliest federal attempts to develop a national acid rain program were begun by the Council on Environmental Quality (CEQ) several years before the 1979 formation of the ARCC. In December 1977, CEQ contracted with four scientists associated with the emerging National Atmospheric Deposition Program (NADP) to develop a plan for monitoring and assessing the effects of acid deposition on aquatic and terrestrial ecosystems. Their report was completed in December 1978 and was a precursor of the draft ARCC plan.

D. Current Federal Programs

Ongoing federal activities provided a foundation upon which the National Acid Precipitation Program was established. In FY 1980, the various federal "mission" agencies spent or obligated about $11 million on research programs directly related to acid rain; approximately $13 million was spent or obligated in 1981, with over $18 million expected for FY 1982 activities. The President's FY 1983 request to Congress proposes a $22 million level for federal acid rain research. Fiscal year 1982 funding levels by agency are shown in Figure 1; Figure 2 illustrates the proportion of funding earmarked for each of the research categories.

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INTERAGENCY TASK FORCE ON ACID PRECIPITATION

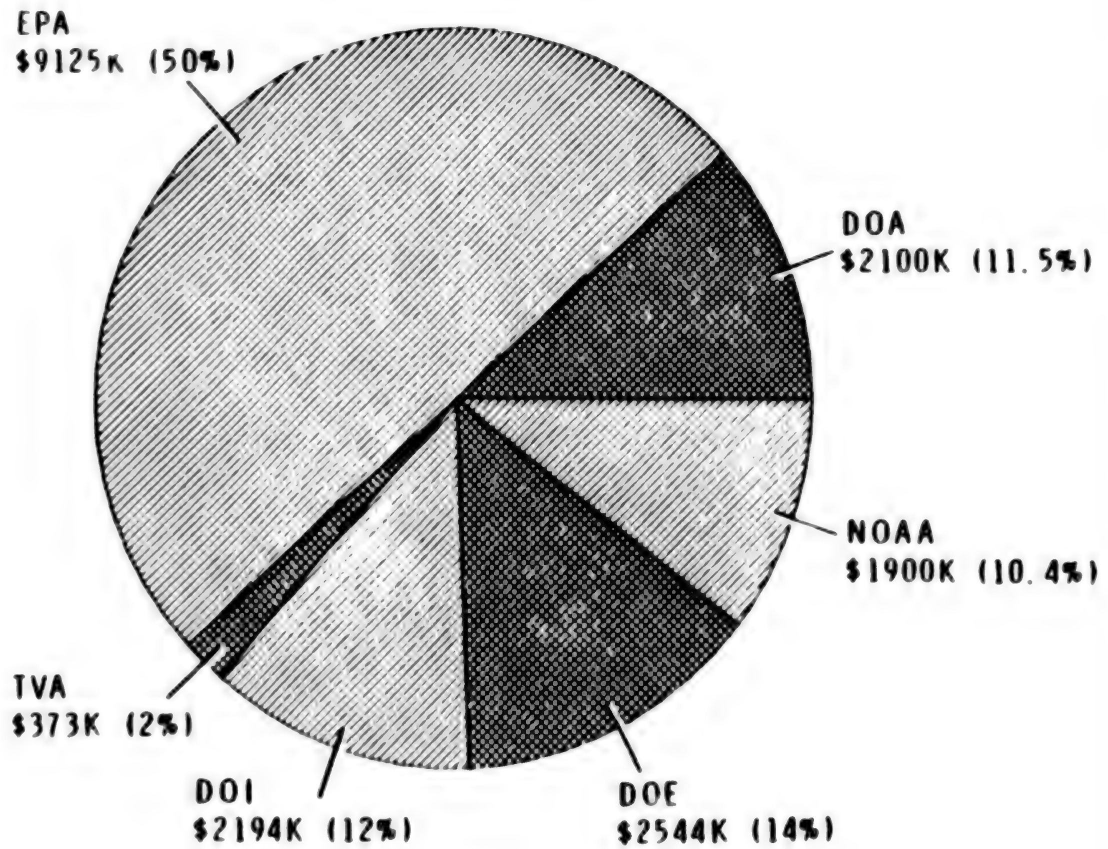

Figure 1. Fiscal year 1982 funding by agency.

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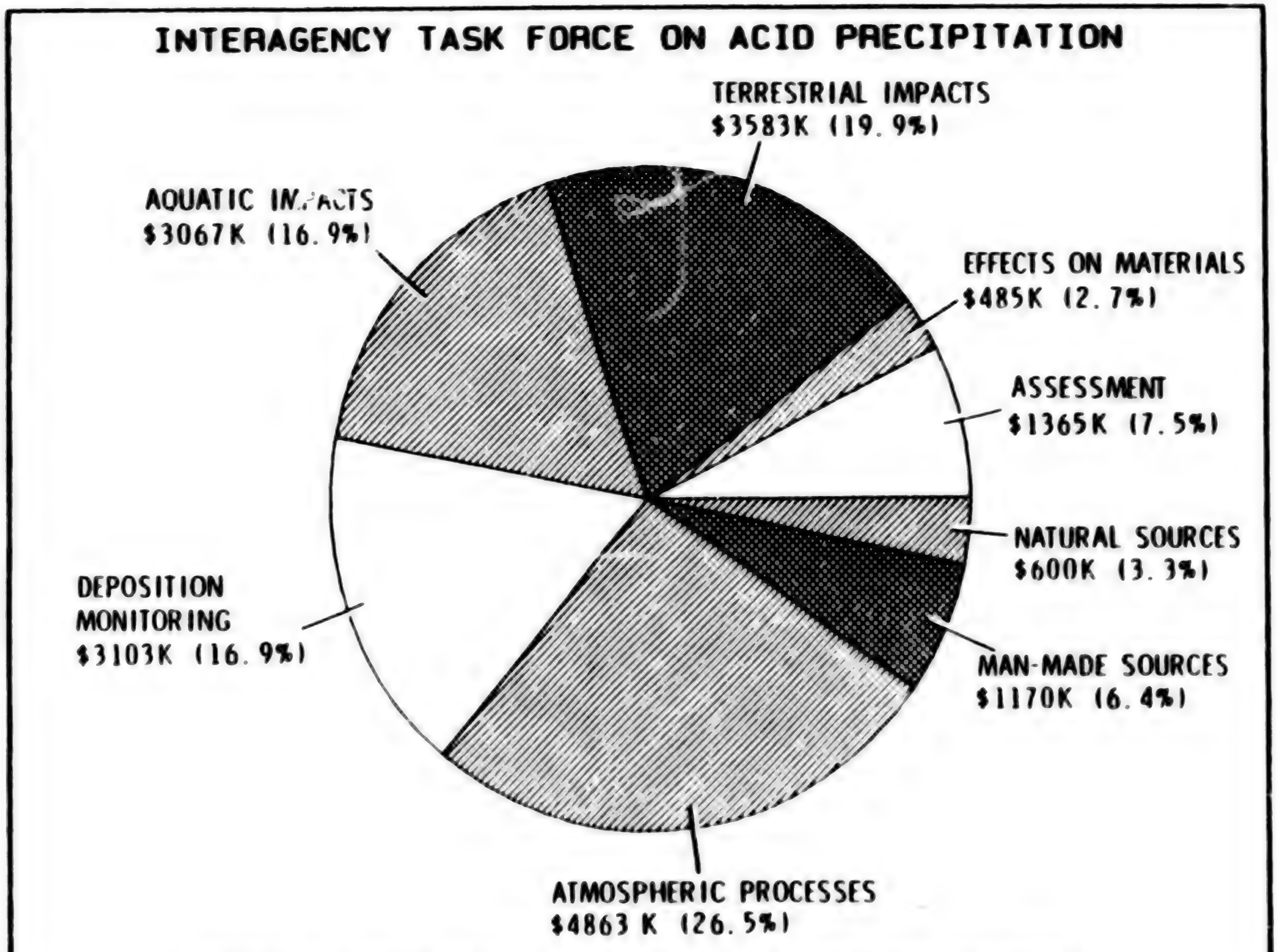

Figure 2. Fiscal year 1982 funding by research category.

The National Program's interagency budget only includes research, monitoring, and assessment activities that are specifically directed toward providing information relevant to crucial policy questions concerning acid precipitation. There are substantial additional efforts supported by participating agencies that contribute in a more indirect way to the information base needed to understand acid rain, such as basic research in ecology, atmospheric sciences and control technology. For instance, the National Science Foundation (NSF) supports extensive basic research programs relevant to acid precipitation. NSF's funding of these activities is not included in the interagency budget, although NSF is a full participant in the Task Force and the studies the Foundation supports are used by, and coordinated with, the rest of the National Program. Similarly, federal support of research and development on control technology is not included in the Task Force's interagency budget. This is because there are many potential reasons for controlling emissions of SO_2 and NO_x which are not directly related to the formation of acid precipitation. However, the Task Force maintains a control technology task group to monitor the federal activities and expenditures on relevant control technologies. The figures presented in the National Acid Precipitation Assessment Program's budget thus represent the core activities of a larger federal effort germane to understanding better the causes and effects of acid precipitation.

The current acid precipitation research programs in the federal agencies with substantial efforts are briefly described below:

DEPARTMENT OF AGRICULTURE (DOA)

The Department of Agriculture is charged with overall responsibility for preserving and strengthening the productivity of agricultural, forest and related natural resources of the U.S. DOA acid precipitation research includes documenting trends in the distribution and intensity of acid rain, determining effects of acid deposition, and identifying ways to minimize harmful effects on crops, soils, forests and rangelands.

The National Atmospheric Deposition Program (NADP) was established to provide a long-term system for monitoring chemical changes in atmospheric deposition and acid precipitation in various regions of the U.S. and to determine the effects of the deposited substances on crops, forests, soils, surface waters, and materials. The program is organized through the regional research program of the Cooperative State Research Service (CSRS) and the State Agricultural Experiment Stations. NADP's monitoring efforts and research activities involve nearly 100 scientists in 22 State Agricultural Experiment Stations, the DOA's Forest Service (FS), the Agricultural Research Service (ARS), EPA, DOE, NOAA, the DOI's National Park Service, Bureau of Land Management, various public and private universities, and industries throughout the U.S. The NADP monitoring network currently includes 90 collection sites in 32 of the 50 States. The objectives of this network have been to measure spatial and temporal trends in acid precipitation and the major nutrient cations and anions in precipitation. Scientists associated with NADP and working at about 50 locations throughout the U.S. are also conducting research on various beneficial effects of atmospheric deposition as well as potential harmful effects of acid precipitation on agricultural crops, forests, soils, surface waters, and materials.

The FS conducts extensive research on the extent, nature, and biological effects of atmospheric deposition. Multi-disciplinary teams of scientists are conducting research at laboratories and in field areas (including over 20 calibrated watersheds). The FS has established eight monitoring sites to enhance the NADP network and additional sites are planned. Specialized studies of the biological and ecological effects of acid deposition on forest vegetation, soils, nutrient cycling, and forest pests are being conducted at eight locations. Much of this work is done cooperatively with universities and other state and federal agencies.

DEPARTMENT OF COMMERCE (DOC)

The National Oceanic and Atmospheric Administration (NOAA) conducts the major portion of the acid-rain related activities of the Department of Commerce. One of NOAA's major missions is to measure and interpret atmospheric and oceanographic parameters to increase understanding of weather and climate. An important aspect of this work is to document and analyze changes in the chemical cycles in the atmosphere. These cycles include: (1) transport of trace substances that enter the atmosphere; (2) chemical transformations that occur during transit; and (3) final removal and deposition of the trace materials on the earth's surface.

To determine where airborne materials would be deposited, NOAA has developed various transport models that are used to investigate phenomena such as the movement of ash plumes from the recent Mt. St. Helens' eruptions. NOAA's Air Resources Laboratories (ARL) operational trajectory model is used to study and predict the transport of acidic materials and their final deposition through precipitation.

NOAA also conducts research on chemical transformations in the atmosphere and the Aeronomy Laboratory (AL) has been especially concerned with photochemical reactions in the atmosphere. The emphasis has been on model, field, and laboratory studies of reactive trace species. Further, NOAA scientists are collaborating on investigation of the reactions that occur in clouds or rain droplets. In acid precipitation research, cloud water chemistry is currently a weak link in our understanding of acid precipitation. In addition, studies are underway to link changes in gas phase concentrations of nitric acid to the acidity of rain as snow.

NOAA began ground monitoring of precipitation chemistry in the mid-1950's, when the first national collection network was established. NOAA - National Weather Service (NWS) facilities have been used as collection sites for many other networks; at present, most of the World Meteorological Organization (WMO) regional and baseline stations also are at NWS locations.

Special studies of data collected at NOAA baseline sites have been useful in determining the background acidity in precipitation. Measurements have been made for over five years in Hawaii, Alaska, Samoa, and Antarctica. These studies are aimed at improving understanding of the long-range transport of both man-made and natural sources of acidic substances, especially in remote areas. NOAA support of university research has included: an intercomparison of precipitation chemistry collectors across the U.S.-Canadian border; the development of new techniques to measure the chemistry of rain on a real-time basis; special studies of dry atmospheric deposition; and atmospheric nitric acid measurements.

The National Bureau of Standards (NBS), primarily in support of the National Park Service, the U.S. Geological Survey and EPA, is conducting research on analytical chemistry and measurement techniques to enhance quality assurance and to ensure measurement comparability and consistency across the nation. NBS has prepared and analyzed three series of reference materials for the chemical analysis of natural precipitation samples to be used as a means of intercalibrating atmospheric monitoring stations. Research has also included surveying the available literature in order to identify the problems and present limitations in the measurement of acidity and pH in rainwater.

DEPARTMENT OF ENERGY (DOE)

The Department of Energy is responsible for overseeing the development of the Nation's energy resources; part of this responsibility includes conducting research on the effects of producing and using energy. DOE's program of acid precipitation research has included work in emissions monitoring, atmospheric processes, ecological effects, and control technology evaluation.

One of DOE's predecessors, the Energy Research and Development Agency (ERDA), recognized that many of the effects of energy use on the environment and health are regional in nature; so ERDA initiated a regional sulfate pollution study in 1976. This study, the Multistate Atmospheric Power Production Pollution Study (MAP3S), had as its major goals the improvement of the Nation's capability to understand and predict the atmospheric effects of emissions from fossil-fueled electric generation plants. The area of study was the energy intensive northeastern quadrant of the U.S.; the emphasis was on understanding the transport and fate of sulfur compounds, particularly sulfates, because of concern over the potential effects of acid deposition. DOE transferred most of its MAP3S program and its major ecological effect studies to EPA in FY 1979. The DOE continues to cooperate with EPA in supporting the MAP3S Precipitation Chemistry Network.

The Environmental Measurements Laboratory, in late 1976, began studies of the effects of the nation's changing patterns of energy use upon the major element and trace element chemical composition of precipitation, dry deposition and total deposition. Samples of wet, dry, and total deposition have been collected monthly at seven sites within the conterminous U.S. The main objective is to obtain data to study possible spatial and temporal trends in precipitation chemistry and in changes in concentration of pollutants in deposition. Any relationship between changing rates of use of various fuels (especially coal) and the deposition trend data will then be examined.

The emphasis in DOE research in atmospheric processes continues to be on the development of improved transport models, improved modeling of deposition processes, and application of these tools to establish source-receptor relationships. DOE researchers are analyzing historical precipitation data to determine whether temporal trends and relationships exist among major ions. Summer convective precipitation is being investigated to determine the spatial variability of acid rain composition as a means for assessing the accuracy of atmospheric deposition estimates. A climatological analysis of three years of Hubbard Brook precipitation chemistry data is being made to determine whether source-receptor relationships can be established.

Ecological research by DOE is designed to provide information on the sensitivity of representative ecosystems and plant species to acid rain, and to begin

to determine the ecological and economic costs of acid deposition. Current cooperative studies include an investigation of the physiological stress of acid water on trout, the effects of acid rain on the leaching of New Hampshire forest soils, and the mobilization of aluminum and calcium by acid precipitation and the eventual interaction of these elements with ground water.

DEPARTMENT OF THE INTERIOR (DOI)

Various Bureaus of the Department of the Interior are extensively involved in the National effort to define the extent of acid precipitation and the actions required to deal with it. This comes about because of the Department's responsibility for the protection and conservation of the Nation's natural resources.

In the area of emission studies, the Bureau of Mines is demonstrating the effectiveness of a process developed for removing the SO_2 gases from power plant stacks. As the administrator of large regions of public lands in the western U.S., the Bureau of Land Management (BLM) is interested in assessing the significance of acid precipitation as it relates to balanced natural resource management. The BLM is responsible for the multiple-use management of various natural resources, some of which (fossil fuels) may produce precursors to acid precipitation, and other natural resources such as forest lands, rangelands, fish and wildlife which may be impacted by acid precipitation. The Bureau operates monitoring stations in nine western states as part of the National Atmospheric Deposition Program.

The U.S. Geological Survey (USGS) is studying the nature of atmospheric dusts and the gases and solid materials emitted by volcanos and geysers. After emissions enter the atmosphere, the Bureau of Reclamation (BUREC) weather modification reseach program is using sophisticated radar, instrumented research aircraft, and other facilities to investigate the rate of vertical mixing and the cloud conditions under which rainout of various materials occurs. Such research is readily adaptable to a full-scale study of acid precipitation. Both the National Park Service (NPS) and BUREC are developing mathematical models of atmospheric transport.

The USGS is providing standards of quality-assurance for the chemical analysis of atmospheric deposition by the Central Analytical Laboratory of the National Atmospheric Deposition Program (NADP). NPS, BLM, and USGS also are operating monitoring sites as part of the NADP. The Office of Water Research and Technology (OWRT) has provided funding for a range of acid-rain related research projects to complement work of other Interior Bureaus.

Atmospheric deposition that reaches the land surface passes over or percolates through the soil before entering streams, lakes, or ground water. USGS soil physicists are studying the movement of water and solutes in the unsaturated zone and USGS hydrologists are studying geochemical processes and developing rainfall-runoff and solute-transport models for both surface water and ground water. NPS also supports research on the chemical changes in precipitation passing through terrestrial ecosystems. The U.S. Fish and Wildlife Service (FWS), NPS and USGS are all conducting investigations on the effects of acid precipitation on lake and stream chemistry. Research on the adverse effects of alterations in water chemistry on plants and animal life also is being supported by FWS and NPS.

The NPS is concerned with the preservation of cultural and historic structures; hence, it is studying means for mitigating the deterioration of structures, some of which may be related to acid precipitation. The Bureau of Mines is also engaged in extensive research on corrosion, some of which is directly applicable to the acid rain problem.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The Environmental Protection Agency is charged with protecting the quality of the air, land, and water resources of the U.S. EPA supports both applied and basic research to obtain better understanding of the environmental phenomenon. A major agency activity is the assessment of environmental research information generated both by EPA and by others. Criteria documents are written when the assessment process indicates that regulations are appropriate. EPA also has primary responsibility for setting control standards for the man-made emissions of precursors to acid precipitation.

EPA maintains a broad research program to provide knowledge and expertise for assessment activities in the acid precipitation area. Participants in EPA supported research include four EPA laboratories, more than 20 academic institutions, and currently, 11 non-EPA governmental agencies and laboratories. The EPA Acid Precipitation Research Program is coordinated by the Office of Exploratory Research within the Office of Research and Development. Research is conducted in five primary areas: monitoring, atmospheric processes, environmental effects, control technology, and mitigation strategies.

EPA efforts to monitor acid deposition include: joint support, with DOA, DOI, and NOAA, of the National Atmospheric Deposition Program (NADP) network; and joint support, with NOAA, of a global acid rain monitoring network. EPA established and maintains the national precipitation chemistry data base. Assessments are underway of the areas in the eastern U.S. that are most sensitive to acid deposition and surveys are being made of the extent to which eastern lakes have been acidified. EPA also has been seeking more accurate ways to measure dry deposition.

Regional atmospheric transport modeling is another ongoing EPA activity, both through the Multistate Atmospheric Power Production Pollution Study (MAP3S) and the regional modeling program at the EPA Environmental Sciences Research Laboratory (ESRL). After the transfer of the MAP3S program to EPA in FY 1979, the study has been redirected toward emphasis on the acid precipitation phenomenon. The goal of this study, run as a multi-laboratory effort by the National Laboratories, involves developing and using transport modeling for SO_2 and NO_x as a means for practical assessments of deposition patterns. The ESRL modeling program, though not entirely tied to acid precipitation research, involves the development of a regional framework model for oxidants and size-speciated particles with SO_2 and NO_x chemistry cycles. The MAP3S and EPA regional models have been used to study both transboundary (U.S.-Canada) air pollution and the impacts of the conversion of power plants from oil to coal. The MAP3S and ESRL programs are developing a coordinated strategy for the development and evaluation of refined acid deposition models.

EPA is also conducting research on the environmental effects of acid precipitation on lakes and streams, drinking water, soils, crops, forests, and materials. EPA has a major cooperative agreement with North Carolina State University to guide the investigation of the effects of acid precipitation on

both aquatic and terrestrial ecosystems. Simulated acid rain studies are being done by EPA on 28 crop species. Work is also being done on the interactive effects of acid rain and gaseous pollutants, and on the accumulation of sulfur in ecosystems. Dose-response research for aquatic systems is underway at experimental sites. EPA also is analyzing past and present acidity of drinking water in New England and New York.

In addition, EPA is evaluating and testing a control technology, the Limestone Injection Multistage Burner (LIMB) process, to reduce both SO_2 and NO_x emissions during coal combustion. The Agency also conducts a wide range of policy studies and assessments related to acid rain.

NATIONAL SCIENCE FOUNDATION (NSF)

The National Science Foundation was established in 1950 specifically to promote and advance scientific progress in the U.S. NSF does not carry out scientific research itself but fulfills its mission by sponsoring scientific research in mathematical, physical, environmental, biological, social, behavioral, and engineering sciences at colleges and universities. Decisions for research support are based on the advice and assistance of advisory committees and other experts to ensure a fair and knowledgeable evaluation. The emphasis within any scientific division (e.g., biology, chemistry, environmental biology) is usually quite broad in order to accommodate the variety of proposals offered. The NSF does not have an assigned or legislated mission for research on acid precipitation or its effects. Understanding acid precipitation, its environmental consequences and possible mitigation are seen in the context of basic atmospheric and biological sciences. Several Divisions and Programs in NSF provide grant support for research either directly or indirectly contributing to the goals of the National Acid Precipitation Assessment Plan.

In the Division of Atmospheric Sciences, support is provided for development and operation of programs and facilities devoted to large scale atmospheric research projects conducted in cooperation with universities (e.g., National Center for Atmospheric Research), government agencies, and other organizations. The Atmospheric Chemistry Program supports research on sources, sinks and intermediate reactions that govern global cycles and budgets of major chemicals in the atmosphere, deposition processes, and basic research on relevant chemical phenomena. Atmospheric Sciences also supports research on the time and spatial dynamics of atmospheric constituents that influence tropospheric-stratospheric transport.

The Division of Environmental Biology supports research in several areas related to understanding acidic deposition and its consequences. Subject areas include ecosystem processes such as decomposition/mineral cycling, primary production and trophic level interactions. Support is provided by studies on soil physico-chemical relationships, soil microbiology, and soil physics as these influence soil nutrient status, transport of water and solutes, and soil-vegetation relationships. This NSF division is a major source of support for biogeochemical studies of entire ecosystems (especially watershed and aquatic ecosystems) which focus on influx/output and the underlying processes influencing cycling of elements, such as nitrogen and sulfur. Most recently a series of projects have initiated studies at a number of sites across the U.S. at which long-term problems can be addressed. Such long-term research can involve experimental manipulation of ecosystems or detailed examination of long-term phenomena such as succession or response to extrinsic variables such as air pollution.

Other NSF programs support development of advanced analytical methodology, physical research and long-term study and analysis of science and technology policy issues.

TENNESSEE VALLEY AUTHORITY (TVA)

During the construction of its first large coal-fired power plant at New Johnsonville, Tennessee, in the early 1950's, the Tennessee Valley Authority became involved in research on the dispersion and environmental effects of power plant pollutants. In cooperation with other federal agencies and research organizations, this effort has continued and includes research on all aspects of power plant pollution, such as emissions characterization; dispersion, chemistry, and long-range transport; fate and effects; and control of emissions.

In 1968, TVA became concerned about the potential problem of acid precipitation and initiated preoperational studies in the vicinity of its Cumberland Steam Plant to determine the local impacts of its emissions on the quality of wet/dry deposition and the forest resources of the area. A wet/dry deposition monitoring network was established at Cumberland in 1971. The network was later expanded to include monitors at five regional air quality trend stations sited in remote areas and at each of its remaining 11 coal-fired power plants.

In 1975, two highly instrumented experimental watersheds were established cooperatively by TVA and EPA on potentially sensitive soils to determine the fate and effects of wet/dry deposition of sulfur on deciduous hardwood forests and the surface waters draining the watersheds. These watersheds and Oak Ridge National Laboratory's (ORNL) Walker Branch watershed are also being used in cooperative research with the Electric Power Research Institute (EPRI) to determine the effects of wet/dry deposition of nitrogen oxides and nitrates on forest ecosystems. In another cooperative study, TVA and EPA have been examining historical water quality data and areas of the Tennessee Valley deemed sensitive to acidification processes. As a part of this same study, laboratory and greenhouse studies have been initiated to determine the effects of acid rain on simulated wetland and stream environments, including cation/anion shifts in pond water due to simulated acid rain runoff from pertinent soil and geological formations and the effects of these changes on characteristic flora and fauna. In FY 1982, studies were initiated to (1) determine the relationship between water quality and wet precipitation and water quality and stream responses in the Southern Blue Ridge province and (2) determine causes of fish kills in aquaculture facilities on the Cherokee Indian Reservation in North Carolina. TVA and EPRI are utilizing forest microcosms to elucidate the effects of various levels of simulated acidic rain on forest species and soils of importance to the region.

E. Nonfederal Programs

Research activites performed by industry, state and local governments, and academic institutions are extensive, with resource commitments of approximately $6 million in 1982. The Task Force will develop and maintain an inventory of federal and state-supported acid rain research. A compatible inventory of private sector activities is also underway, supported by several industry groups and coordinated by the American Petroleum Institute.

A wide range of research activities is sponsored by private sector groups. One example of an ongoing program is that of the Electric Power Research Institute (EPRI), whose acid precipitation research budget for FY 1982 is $3.4 million. EPRI supports peer-reviewed research through various universities and private contractors and all the information generated is public. Three groups in EPRI's Energy Analysis and Environment Division are responsible for acid precipitation work: the Environmental Physics and Chemistry Program manages the research on formation, transport, and deposition of acids; the Ecological Studies Program manages the ecological effects and mitigation work; and the Technical Staff are responsible for carrying out the economic evaluations.

EPRI's research into chemical transformation processes and transport include cloud chamber studies, instrument development, and applications of cloud models to identify important chemical mechanisms. The Sulfate Regional Experiment (SURE) study is attempting to develop a means of predicting concentrations of a secondary pollutant (sulfate) in terms of local emissions of its precursor (SO_2). EPRI's cloud chemistry research has included a study of plumes with tracking by instrumented aircraft over the North Sea, and will include instrumented aircraft sampling of cloud chemistry over the eastern U.S.

The Ecological Studies program includes studies of aquatic systems as well as natural and managed terrestrial ecosystems (such as crops, forests, and grasslands). The Integrated Lake-Watershed Acidification Study (ILWAS) is attempting to determine the relative role of acid precipitation in the acidification of surface waters and to develop a predictive model of watershed acidification. The acid precipitation at the three lakes in the ILWAS study has been monitored as part of the Environmental Physics and Chemistry Program.

Terrestrial flora research includes studies of the effects of acid precipitation on agricultural crops in the northeastern, midwestern, and southeastern U.S. Studies monitoring the effects of acid rain on nutrient status of forest ecosystems are being carried out, as well as microcosm evaluation of acidic deposition on forest ecosystems. Research studying acid-rain/forest-canopy interactions is also being undertaken.

A few substantial acid precipitation research programs sponsored by state governments are currently underway, while other states are actively examining the possibility of establishing such programs. An example of a state with an extensive acid precipitation research effort is Wisconsin where the program has a research budget for FY 1982 of about $1.4 million. In September 1980, representatives from the Wisconsin State Task Force on Acid Rain, the Wisconsin Utilities Association Task Force, the Public Service Commission, and the Wisconsin Paper Council, formed a Joint Acid Deposition Technical Review Committee. The purpose of the Joint Committee is to integrate the various acid deposition research strategies into one comprehensive research plan for the State of Wisconsin.

Project activities outlined in the plan for 1981-1983 include: expanded precipitation monitoring; atmospheric trajectory studies; watershed studies; the identification of source regions through the use of long-range transport models; and establishing a deposition data management effort. The Wisconsin plan also contains the following three project areas which would be supported if given additional funding: feasibility studies of source control strategies;

acidification studies of headwater streams; and the compilation and evaluation of mitigation measures.

This exemplary state program reflects an integrated effort by state and private sector groups.

II. OVERVIEW OF THE PHENOMENON AND CONSEQUENCES OF ACID RAIN

The origins and consequences of acid precipitation are complex, and our understanding of them is incomplete. This part of the plan briefly summarizes what is known and hypothesized about acid precipitation and its effects. The specific unknowns and uncertainties in our knowledge of the phenomenon are addressed in Part III.

A. Definitions

Some widely used technical terms that relate to "acid rain" are defined as follows:

pH - pH numbers indicate the acidity, i.e., the free hydrogen-ion concentration or activity in a solution. Each unit of decrease on the pH scale represents a 10-fold increase in acidity. A pH of 7 is neutral, a pH of less than 7 is acidic, and a pH of more than 7 is alkaline.

Acid rain - A popular term with many meanings but most properly used to describe precipitation with a pH of less than 5.6 (see below).

Acid precipitation - Throughout this plan, as in the Act (P.L. 96-294), this term is used in a general sense, including both wet and dry deposition of acidic substances (see below). Scientists typically use this term in a more limited way to refer specifically to water in the form of rain, sleet, snow, and hail, with a pH of less than 5.6. A pH of 5.6 is the theoretical reference point because in a completely clean atmosphere, the carbon dioxide in the air would dissolve in water (e.g., distilled water) and form a dilute solution of carbonic acid approximating this pH. In the actual atmosphere this theoretical value rarely occurs because of natural and man-made gases and particles that are incorporated into the rain and influence the pH value.

Wet deposition - A term that refers to (a) the amount of material transferred from the atmosphere by rain, snow, or other precipitation forms; and (b) the process of transferring gases, liquids, and solids from the atmosphere to the ground during a precipitation event.

Dry deposition - A term for (a) all materials deposited from the atmosphere in the absence of wet deposition and (b) the process of such deposition. The three major dry deposition processes are (1) gravitational settling of coarse particles or dustfall (usually more than 2.5 micrometers in diameter); (2) impaction of fine particulate aerosols (usually less than 2.5 micrometers in diameter) by air motion; and (3) the absorption or adsorption of gases. All three removal processes deliver substances from the atmosphere to exposed surfaces such as plants, soils, water bodies, and man-made structures.

Acid deposition - The wet or dry deposition, or transfer from the atmosphere to the ground of acidic subtances. Note that neither rain nor snow is pure water. The acidity of precipitation is determined not by a single substance but by a complex mixture of partially or completely dissociated acidic and alkaline substances. Thus, the pH of precipitation is determined by the net effects of the interactions among all of the positively

charged ions (cations) and negatively charged ions (anions) dissolved in the water.

Atmospheric deposition - A term broader than acid deposition, covering the transfer from the atmosphere to the ground of all types of gases, particles, and precipitation constituents included in both wet and dry deposition. Atmospheric deposition includes many different types of substances, non-acidic as well as acidic.

B. Evidence of Changes in Precipitation Acidity

The chemical composition of atmospheric deposition has never been monitored consistently in North America over any extended period of time. Monitoring networks established in the past have acquired useful data, but all have been dismantled after relatively short periods of operation. There is also insufficient information on data collected by these networks to permit establishing sample validity, data quality, and other parameters of quality assurance.

The first U.S. nationwide network was in operation from July 1955 to July 1956.[1/] Between 1960 and 1966, the Public Health Service (PHS), and later the National Center for Atmospheric Research (NCAR), operated a 33-station national network; the data from this network have never been adequately analyzed nor were all data of current interest.[2/] A 17-station national network has been operated in the U.S. for the World Meteorological Organization (WMO) since 1972, but questions on the validity of samples collected on a monthly schedule have led to uncertainties about much of the earlier data.[3/, 4/]

Several other state or regional networks have been operated for various purposes and for limited periods of time. The Multi-State Atmospheric Power Production Pollution Study (MAP3S) precipitation chemistry network, which began to operate in 1976, provided the first regional event-sampling data involving four sites in the northeast. The MAP3S network was later expanded to eight sites.[5/] Monitoring data collected by the National Atmospheric Deposition Program since 1978 are available.[6/] A similar national network was established in Canada in 1976.

There is considerable controversy about our ability to document trends in precipitation acidity over the last several decades. The acidity of precipitation has only been measured consistently for nearly two decades in one place in North America -- the Hubbard Brook Experimental Forest in New Hampshire, and no marked trend in pH is evident in that record. None of the networks of the past have measured dry deposition adequately. Because of the general lack of consistent monitoring in the past, long-term trends in acid deposition in North America are poorly defined.

Detection of actual trends in precipitation acidity is complicated by the fact that apparent trends in the strength and distribution of acid deposition can result from: 1) differences in measurement techniques and analytical methods; 2) year-to-year variations due to changes in neutralizing dusts (due, in turn, to changes in levels of precipitation); 3) changes in levels of alkaline particulates due to environmental controls; and 4) combinations of the above.

Using the limited data available, the intensity and geographical distribution of acid precipitation in 1955-56, 1965-66, and 1976-79 have been compared.[7/]

Such distributions from different measurements should not be interpreted as definitively as establishing a long-term trend. They can, however, be used to suggest the possible spreading and intensification of precipitation acidity.

An adequate monitoring data base for confidently documenting trends in acid rain has only existed in North America since about 1978. Figure 3 shows the best currently available map of acid precipitation derived from NADP and CANSAP data for 1980. These data serve as points of reference for the determination of future trends in acid precipitation.

It is essential that all future monitoring efforts be standardized, coordinated, and documented. The quality of data can be established only when proven methods of collection, analysis, and quality assurance are used. Quality precipitation chemistry data are needed both for short- and long-term purposes. Such purposes include (a) specific forecasts of what regions are likely to be affected by acid deposition, (b) validation of models of long-range transport, and (c) systematic evaluation and adjustment of control and mitigation measures.

Direct measurements of precipitation pH are not the only sources of information relevant to the possibilities of long-term changes in the chemistry of rain and snow. Other records relevant to the problem include the following:

1. Changes in the alkalinity of municipal reservoirs and lakes. A particularly good record (1924-1980) is available for the Hinkley Reservoir near Utica, New York[8/];

2. Changes in the amounts and patterns of fuel use in the U.S. and Canada since industrialization began about 1850; and

3. Changes in the sulfate concentration of precipitation accumulated in the Greenland icecap since the early 13th century.[9/]

Analysis of this information suggests the following:

- Precipitation in the eastern parts of the U.S. and Canada has probably increased in acidity since the industrialization of these regions, but a quantitative assessment cannot be made with the data currently available; and,

- Although the pH of rain and snow west of the Mississippi River is often above 6 (mainly because of alkaline soil blown into the air), acid rain has been reported in some urban and remote areas in the western U.S. Also, the acidities of contemporary rain and snow events in the northeast are often about pH 4, sometimes above pH 5, and occasionally close to pH 3, mainly because of an excess of acidic substances in the air.

C. Sources of Acid Precipitation

The primary cause of acid precipitation in industrialized regions of the world is believed to be man-made emissions of acid-forming material. The major precursors of acid deposition appear to be two gases -- sulfur dioxide (SO_2) and oxides of nitrogen ($NO + NO_2$)-- that originate from both natural and man-made sources. Some natural sources emit precursors of SO_2, such as

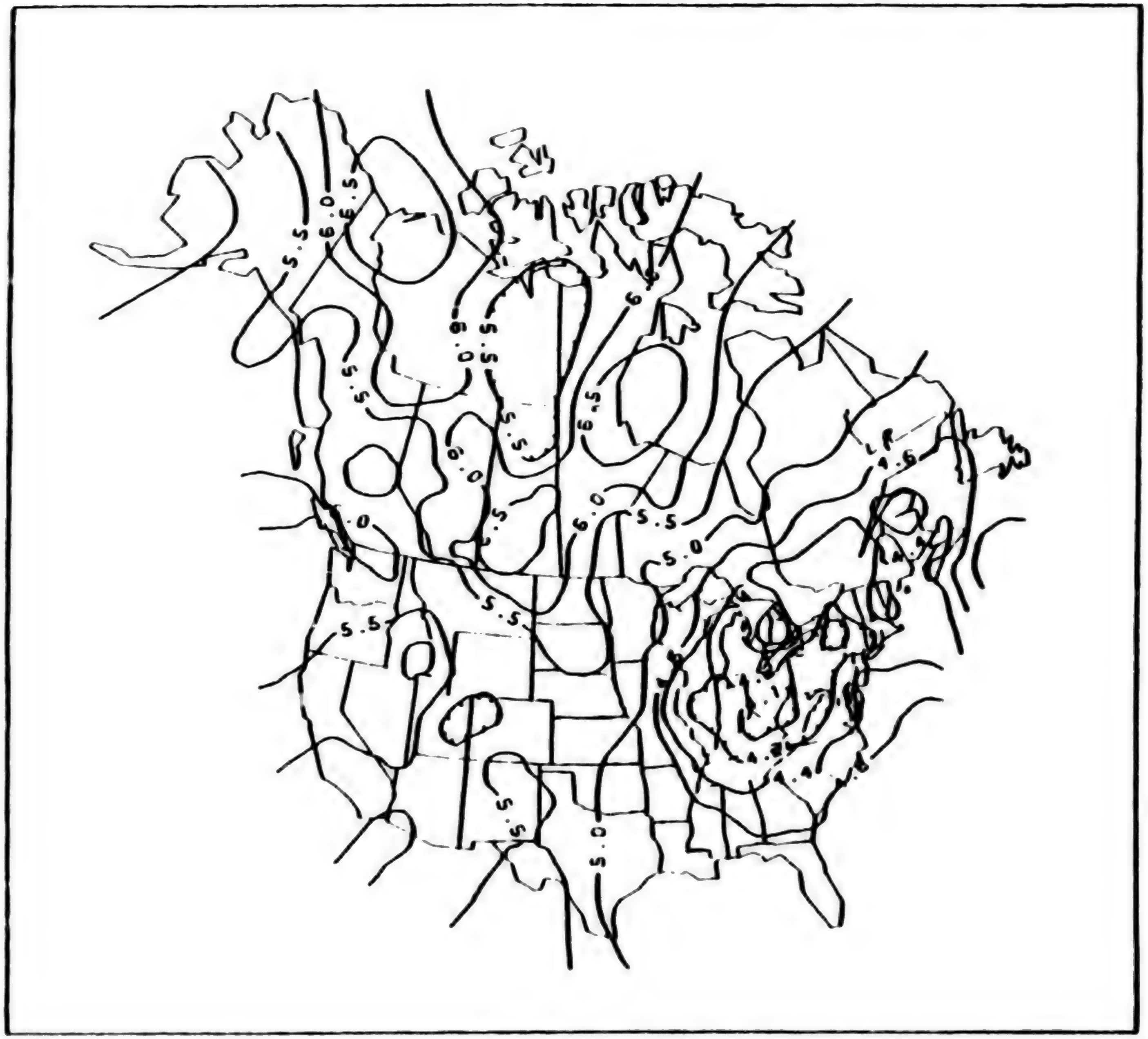

Figure 3. Precipitation weighed pH isopleth map, January-December 1980. (Prepared by J.H. Gibson and C.V. Baker from NADP and Canadian CANSAP data.)

hydrogen sulfide (H_2S) and organic sulfides (COS and CS_2). Other natural sources, such as volcanoes, can emit large amounts of SO_2 and other precursors of acid deposition. Wildfires, sea spray, lightning, decomposing organic matter, and living vegetation also can lead to the release of significant amounts of sulfur and nitrogen compounds that may contribute to the formation of acid rain. Globally, the relative magnitudes of natural and man-made emissions of the two gases are uncertain. In the eastern U.S. and adjacent parts of Canada, however, man-made emissions of sulfur dioxide are estimated to be substantially larger than natural emissions.[10/] Emissions other than SO_2 and NO_x also may be important in the formation of acid precipitation, such as volatile organic compounds, directly emitted acids, chlorides and particulates (acidic, neuturalizing and cataylic). For instance, it is possible that the formation of acid sulfates are limited by available oxidants.

Figure 4 shows a hypothetical sequence of environmental events which could result in the acidification of precipitation. Industrial pollutants are released into the atmosphere from the tall stack of a plant or transportation source burning fossil fuel. Exhaust emissions from automobiles and trucks are added to the industrial pollutants. Arrows drawn in the figure toward the rain cloud indicate atmospheric transport of pollutants, which can be for hundreds, sometimes thousands, of miles. Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are subject to chemical transformation in the atmosphere, in the clouds, and in precipitation events. Acid is deposited by the atmosphere in both wet and dry forms on trees, crops, soil, lakes, and man-made structures. Local sources of SO_2, NO_x, and other pollutants also may have important effects on biota, soils, aquatic ecosystems, and materials, and could be the dominant factors in some areas.

In 1977, total man-made emission of SO_2 in the U.S. was estimated to be about 29.9 million metric tons. Of this amount, 24.3 million metric tons (81 percent) came from fuel combustion in stationary sources such as electric utilities, large industrial plants, and commercial and residential heating systems. Estimated man-made emissions of NO_x in 1977 was 23.1 million metric tons. Of this, 9.7 million metric tons (39 percent) came from transportation (combustion of gasoline or other fuels in cars, trucks, planes, trains, etc.), and 15.3 million metric tons (61 percent) from combustion in stationary sources.[11/]

Between 1970 and 1977, annual man-made SO_2 emissions in the U.S. declined about 10 percent because of abatement strategies; however, during the same period, NO_x emissions increased by about 17 percent. It is estimated that over the next 20 years, annual emissions of man-made SO_2 will increase slightly to about 30 million tons, with approximately 18 million tons expected to come from electric utilities (Fig. 5). NO_x emissions, in contrast, are expected to increase significantly. By the year 2000, NO_x emissions are anticipated to increase roughly 16 percent, to about 27 million tons per year (Fig. 6). This increase is not expected to come from the transportation sector, where fuel use will probably be declining. Rather, it may come from stationary sources. This set of projections is only one of a number of possible scenarios.

The ratio of sulfuric to nitric acid in precipitation is variable both in time and place. In general, sulfuric acid values are lower in the western U.S. than in the East, and mobile sources of NO_x appear to play a more

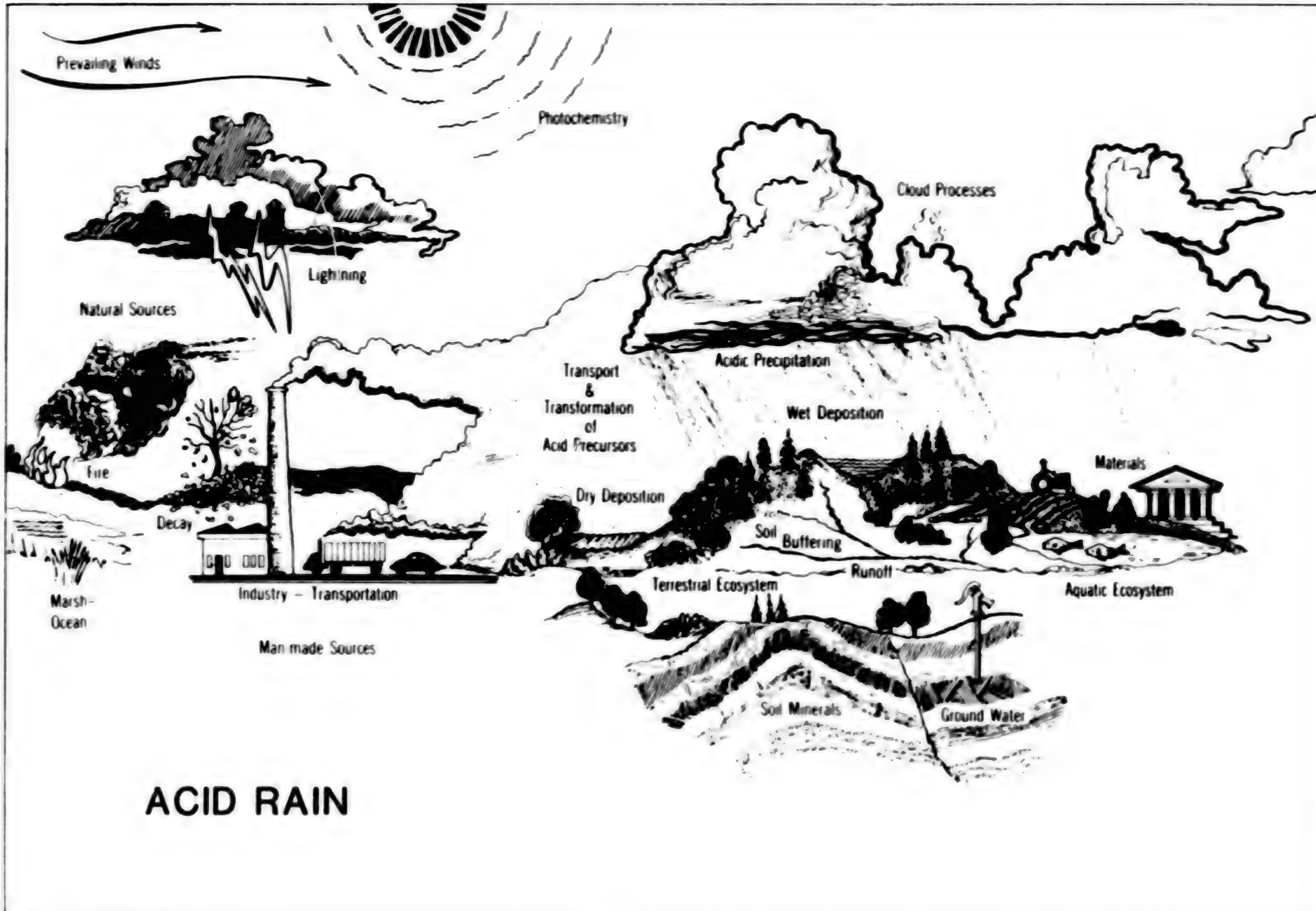

Figure 4. Schematic representation of the phenomenon and consequences of acid precipitation.

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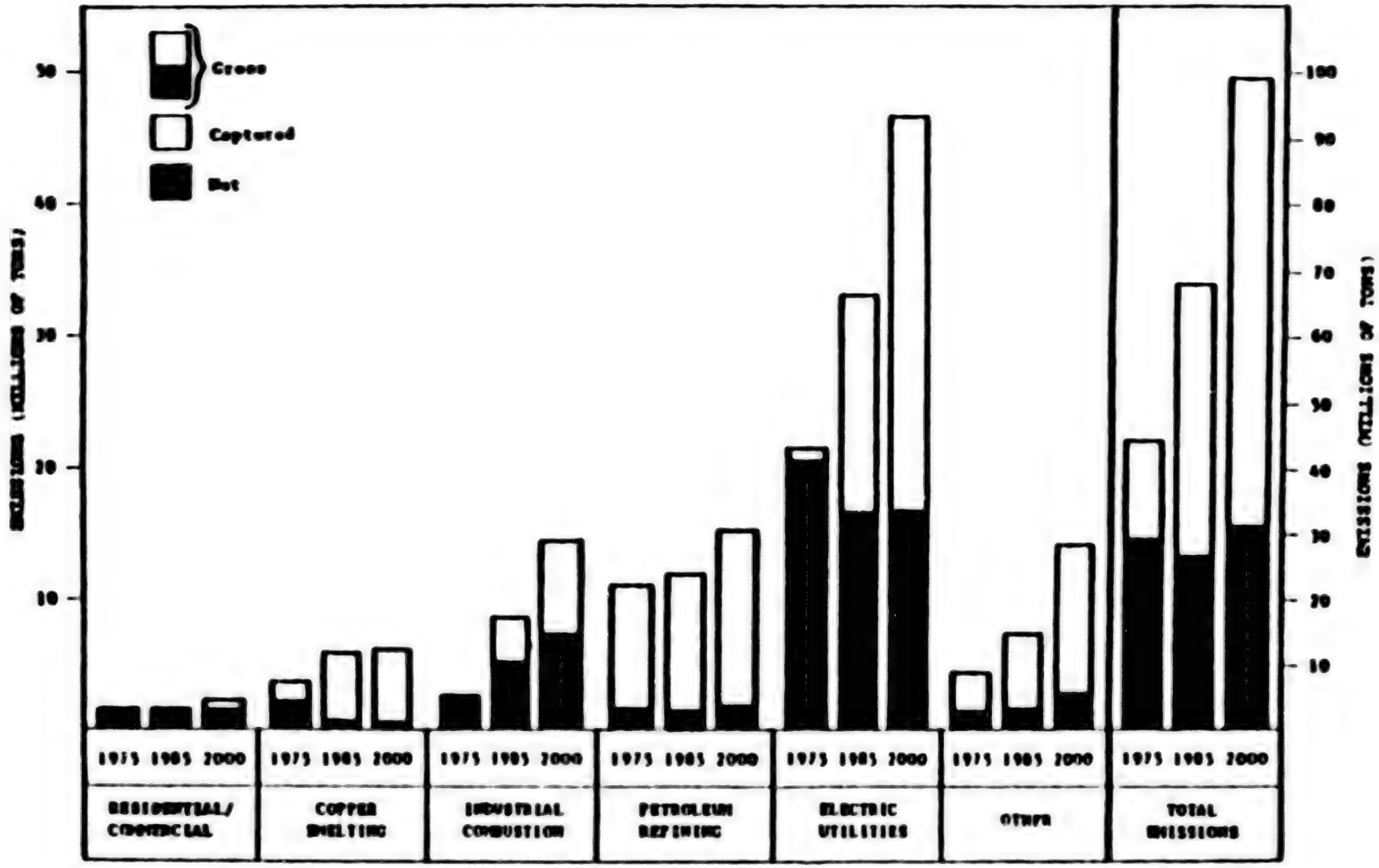

Figure 5. Trends in sulfur oxide emissions, by source for 1975, 1985, 2000. Assumes total energy supply expanding at 2.1% per year from 1975. [From "Environmental Outlook 1980," U.S. EPA]

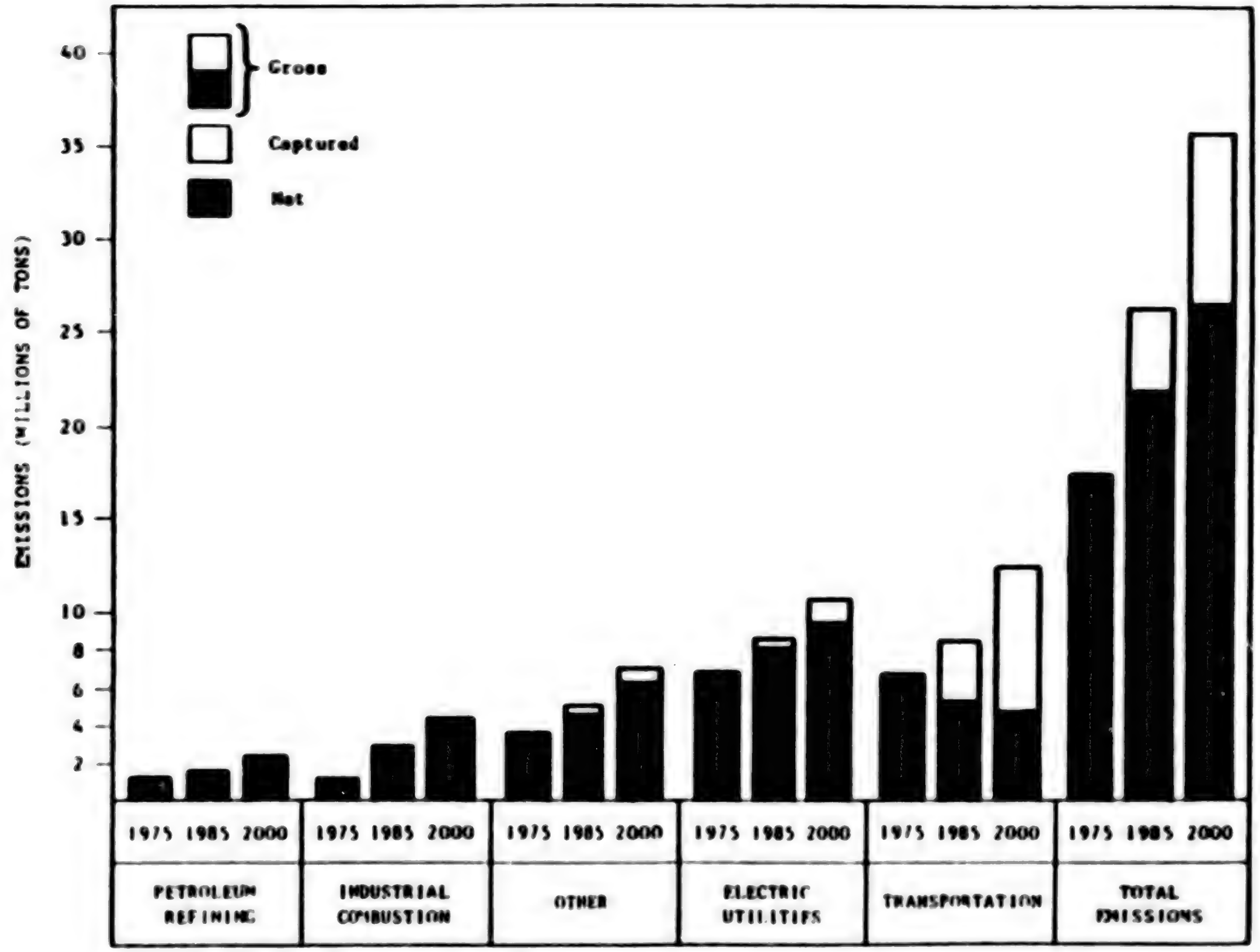

Figure 6. Trends in nitrogen oxide emissions by source for 1975, 1985, 2000. Assumes total enery supply expanding at 2.1% per year from 1975. [From "Environmental Outlook 1980," U.S. EPA]

important role in the formation of acid precipitation in the West.[12], [13], [14] As emissions of NO_x increase more rapidly than SO_2 emissions, nitric acid is expected to play an increasing role in acid deposition. Furthermore, nitrogen oxides have a role in oxidant formation and thus could have a greater significance to acid precipitation formation than indicated by the ratio of sulfuric to nitric acid in rainfall.

In addition to the principal sources, "secondary" contributors or inhibitors are important in the formation of acid rain. Ammonia is generally found as an alkaline vapor able to neutralize either sulfuric or nitric acid in the atmosphere and will, therefore, tend to increase the pH of rain and snow. However, as ammonia dissolves to form ammonium (NH_4 +), the presence of this ion may increase the conversion rate of sulfur dioxide to sulfurous acid, and finally into sulfuric acid in the atmosphere. Most ammonia emissions are released into the atmosphre by natural and biological processes, such as the decay and decomposition of organic matter, forest fires, and volatile emissions from land and ocean masses. Anthropogenic sources account for a small percentage of the total ammonia emissions.

Despite its low but significant percentage in precipitation, hydrochloric acid (HCl) is a strong acid whose sources and mechanisms of formation have not been completely identified. The natural sources of chloride include salt spray from the oceans, volcanic gases, and upper atmospheric reactions. Anthropogenically produced chlorine and chlorides are emitted in various manufacturing and process operations; primarily in the manufacturing, handling, and liquefaction of chlorine gas and HCl. The combustion of coal by power generating facilities also releases chlorides into the atmosphere because central U.S. and Appalachian coals contain chlorine.

Ozone and other photochemical oxides play a role in the conversion of SO_2 and NO_x to sulfates and nitrates, respectively. Although the reactions of these substances are largely a matter of speculation and hypothesis at this time, further research can be expected to reveal the extent of their contributions to the formation of acid precipitation.

Another factor in the formation or neutralization of acid precipitation is the presence of natural and man-made dusts. Many natural dusts are alkaline and may react with and neutralize strong acids in the atmosphere. A similar role has been postulated for coal-fired boiler fly ash emissions, which are often alkaline. Fly ash may play a more direct role in acid rain formation by catalytic oxidation of SO_2 by metallic constituents, such as vanadium pentoxide, or by absorption-oxidation in the presence of large amounts of water. Vanadium pentoxide, for example, is also formed in the combustion of residual oil and, therefore, may influence the fate of SO_2 from oil-fired power plants. The catalytic oxidation of SO_2 to $SO_4^=$ needs much greater study, as it may be an important route in the transformation of SO_2 to $SO_4^=$ particulates.

D. Atmospheric Transport and Chemistry

Once in the atmosphere, sulfur dioxide and nitrogen oxides undergo complex chemical and physical transformations. These gases and particles combine in complicated and uncertain ways with water, oxidants, ammonia, heavy metals,

hydrocarbons, and other airborne materials to form the complex and heterogeneous mixtures of substances that return to the earth's surface as wet and dry deposition.

Depending upon meteorological conditions and circumstances of release, sulfur and nitrogen oxides can either be dispersed locally or transported hundreds to perhaps thousands of miles from their point of origin. Understanding the transport of sulfur and nitrogen oxides and their acidic oxidation products is probably one of the most important aspects of acid deposition. It has been inferred that acids deposited in Scandinavia may frequently derive from emissions originating in England, Germany, or Poland. Similarly, a portion of the acid deposition in the northeastern U.S. and Canada is thought to be due to SO_2 and NO_x that originates outside of these areas.

Preliminary measurements at remote island sites in the Pacific and Indian Oceans -- far from man-made sources -- indicate that acid rain may be a global as well as a regional phenomenon. But because the natural sources and transport processes are not adequately understood, it is difficult to state what portion of acidity at these remote locations is man-made and what portion is natural. Although such long-range transport is becoming better understood, it is still not possible to determine the extent to which any specific source or collection of sources in one region leads to acid deposition in another region.[15/] In addition to the importance of the atmospheric transport and chemistry of sulfur and nitrogen oxides, there can be a significant contribution of primary acid sulfates from petroleum derived fuels, on local and regional scales.

E. Effects of Acid Precipitation on Biological Systems

Many uncertainties exist in assessing the biological and related effects of acid deposition. Impacts of acidification on aquatic ecosystems have been documented and considerable concern exists about the potential effects of acid precipitation on crops, soils, forests, rangelands, wetlands, and human health. Studies to date have not provided clear evidence of damages to terrestrial systems from acid precipitation under field conditions, however, damages due to oxidants and local sources of pollutants have been demonstrated.

In Scandinavia, hundreds of lakes are now devoid of fish and projections by Swedish scientists indicate that thousands more may become excessively acidic by the year 2000.[16/, 17/, 18/] Eighty percent of the brown trout population in Norway's southern lakes could be lost by 1990 if present trends continue.[19/] Scientists in North America are also concerned that certain lakes in the U.S. and Canada could eventually lose their ability to sustain populations of fish and other aquatic organisms due to acidification.

The effects of acid deposition on aquatic life are not documented as comprehensively in this country as in Canada and Scandinavia. However, it is known that many lakes in the Adirondack Mountains, New England, and the upper midwest are showing apparent stress from increased acidity, and that lakes and streams elsewhere in the U.S. also appear to be vulnerable.[18/, 20/]

Sudden increases in acidity are generally more harmful to fish than gradual changes. These surges can occur when a winter's accumulation of acid-laden snow and ice melts in the spring and runs into lakes, streams and rivers, or following periods of intense rainfall. Such short-term concentrated releases

of pollutants can cause major and rapid changes in the acidity and other chemical properties of the receiving waters. Fish kills have been a dramatic consequence of such episodes.[21/] The effects of acid deposition on fish and other aquatic life depend not only on the amount of acidification and its timing, but also on the lifestage of the affected organisms. In the early stages of reproduction, fish and fish food organisms are particularly vulnerable to rapid changes in the chemistry of surface waters.

The severity of the effects of acid content surges and of gradual, longer-term increases in acid deposition also depend on the chemical properties and size of the body of water affected, and on the geochemistry of the drainage basin. By chemical interactions or filtering effects, many aquatic systems have a natural capacity for neutralizing, or offsetting, the deposition of acids. Other waters, particularly where the watershed is underlain by granite bedrock or dominated by acid soils, have little or no buffering capacity. The Adirondack and Appalachian regions, and significant portions of New England, Michigan, Wisconsin, Minnesota, Washington, Oregon, and parts of California and Colorado are underlain by granitic bedrock and hence are likely to contain some lakes particulary vulnerable to impacts by acid deposition.

Total reproductive capacity of fish is impaired not only by the acidity of the water itself, but also due to the acids mobilizing certain toxic metal ions, particularly aluminum, from soils. The toxic ions may originate in the watershed, lake-bottom sediments, or may be introduced directly in wet or dry deposition. Toxic ions that occur in wet or dry deposition, sediments, and soils include those of the elements manganese, zinc, copper, iron, iodine, boron, flourine, bromine, aluminum, lead, nickel, cadmium, vanadium, mercury, selenium, and arsenic. The first five are essential micronutrients that are required by plants and animals in small amounts. However, at concentrations sufficiently above the required levels, these elements can be toxic to aquatic life. The remaining elements listed also can be toxic to plants or animals when present in large amounts.

Much less is known about the possible effects of acid deposition on crops, forests, and soils. Acid deposition may be either beneficial or detrimental to agricultural crops and forest vegetation. A beneficial effect could occur by the action of acid deposition in offsetting part of the sulfur and nitrogen deficiencies in many soils in the U.S. Nitrates and sulfates are important plant nutrients, so those supplied by acid deposition might stimulate the growth of plants where there is a deficiency. Genetic variation often is responsible for wide variations in the responses of organisms to acid precipitation.

On the negative side, labatory and field studies suggest that excess depositions of acids can have adverse effects. These include direct damage to the leaves and roots of some plants, interference with the biological fixation of nitrogen, and predisposing plants to injury by diseases, insects, and other environmental stresses. Acid deposition may also affect vegetation through cellular damage from low pH exposure, which can weaken natural defenses to insect and disease stress and compound problems with other pollutants (e.g., ozone, PAN). Of particular concern is the possibility that soils might be irreversibly degraded or impoverished as a result of sustained acid deposition; at present, there is little information about this effect. Whether such

effects on vegetation and soils are occurring at present levels of precipitation acidity is uncertain. No such consequences have yet been documented under actual growing conditions in the field.

Means of mitigating the actual effects of acid deposition have received relatively little attention in this country. Possibilities include the use of neutralizers such as lime in lakes and streams and of similar substances in soils; also possible is the use of protective coatings and treatments of man-made materials. Selective breeding programs might improve the tolerance of some crops, trees, and fish to acidic environments.

F. Effects on Materials and Cultural Resources

Acid precipitation may affect materials through direct atmospheric contact, through acidification of natural waters in contact with materials, and through acidification of soils. Exposure to atmospheric acidity may affect metallic roofing (e.g., copper, galvanized steel), structural steel, automobiles, electronic equipment, bronze statues and other monuments, paints, some plastics, concrete structures, stone structures, and the mortar used in masonry structures. Exposure to acidity in natural waters may lead to the corrosion of metals (e.g., as used in pumps and bridge supports), the leaching of lead and other trace metals from water pipes, and perhaps the leaching of toxic chemicals from plastics. Soils of high acidity may accelerate the corrosion of buried structures and equipment such as pipelines, power cables, and transformers.

It is difficult to distinguish the effects of acidic precipitation from damage induced by sulfur pollution in general because sulfur species (especially SO_2) are a dominant factor in the formation of acidic precipitation. Isolation of the impacts of acidic precipitation from the impacts associated with other constituents of the ambient atmosphere is extremely difficult. Current understanding of material decay processes tentatively indicates that local sources of pollution may overwhelm the effects resulting from long-range transport of acid deposition in urban or industrial areas where most abnormal material damages are found.

Acid depositions, oxidants, corrosive gases, and particulate pollutants all can contribute to the accelerated degradation of materials. Plastics, elastomers, paints, and organic coatings are degraded by actinic, photochemical, and chemical processes and by acid-catalyzed polymer decomposition. Particulates adversely affect the appearance of surfaces and can cause retention of reactive chemical species. In structures, acid and other sulphur compounds in combination with salts or particulate deposition could be causing damage to painted surfaces, historical monuments, porous stone and bricks, colored glass and plastics, bridges, and road culverts.

Many typical metallic construction materials may be adversely affected by acid deposition through galvanic corrosion and increased dissolution of protective surface oxides or of the metal itself. Metals such as zinc and copper, whose corrosion resistance depends on layers of oxides, sulfates or carbonates, are probably most susceptible to damage by acidic precipitation. Oxidants might be less damaging to metals and may lower metallic corrosion rates through surface passivation. Certain specialized metallic electronic components have been shown to be very sensitive to pollutants, particularly SO_x species.

Masonry materials exhibit a wide range of responses to pollutants. Carbonate-containing materials, such as limestone or marble, are very susceptible to attack by acid deposition. Masonry materials containing large amounts of silicates (e.g., concrete) are more resistant to most acidic atmospheric pollutants. However, reinforcing steel within concrete may be susceptible to attack. Wood materials in construction are generally resistant to weak acid deposition, but are known to be attacked by oxidants.

To protect materials from the various air pollutants, coatings can be applied to both monuments and buildings. If weathering of the finish accelerates with increased pollutant deposition, then the cycle for refinishing could be adjusted. Attempts to shield threatened masonry structures with protective coatings have not generally been successful; they are subject to adhesion failure and often cause spalling of the substrata material.

Historical monuments and cultural heritage sites are also subjected to the effects of atmospheric deposition. Methods need to be devised for measuring this damage in terms of significant aesthetic, cultural, and historical values. When the sheer volume of materials exposed to wet and dry deposition is considered, the importance of determining the relationship between normal weathering, exposure to acid deposition and other pollutants, and economic cost is apparent.

G. Relationship to Human Health

Acid precipitation is unlikely to have important direct effects on human health. Indirect effects are possible due to acidification of drinking water, eating fish from acidified lakes and streams, and consuming leafy vegetables which have been subjected to deposition of acidic substances and heavy metals.

The health effects related to inhaling sulfates and other particulate or gaseous air pollutants is a subject far broader than the acid rain issue. The National Acid Precipitation Assessment Program is focused specifically on the causes and consequences of the deposition of acidic substances. Other federal programs are being conducted to address the wider range of problems associated with airborne pollutants, such as the criteria pollutants health effects research performed by the EPA, as mandated by the Clean Air Act. This research is used in the establishment of ambient air quality standards.

Acidification of large drinking-water reservoirs has been reported in the U.S.[22/] This acidified water could dissolve both lead and copper in plumbing systems and thus indirectly affect human health, especially if the exposure to the dissolved metals were sustained over a long period.[23/] Acidification of well water could have the same effect; evidence from western Sweden indicates not only that some well waters have become increasingly acidic, but also the heavy metal content of these waters has increased.[24/]

Indirect effects also may occur in the human food chain. For example, fish caught in acid waters in the U.S., Canada, and Sweden show higher concentrations of metals than fish taken from nonacid waters.[25/] Similarly, absorption of heavy metals by plants or the deposition of heavy metals on plants could affect human health through the food chain.[26/] It should be emphasized, however, that there is little evidence to suggest that such effects have yet occurred in North America.

In this Plan, the potential indirect impacts of acid deposition on human health are examined in the sections on aquatic impacts and terrestrial impacts.

H. Control Technologies

The principal man-made sources of SO_2 and NO_x are fossil fuel power plants, industrial boilers, smelting operations, residential and commercial heating, and internal combustion engines. NO_x originates partly from atmospheric nitrogen and partly from fuel nitrogen. SO_2 originates from fuel sulfur, and is generally most abundant in coal although also present in oil and gas. The percentage of SO_2 and NO_x originating from natural sources is still unknown and control of these emissions is unlikely. Several types of controls are being used or are being developed to limit the emission of SO_2 and NO_x into the atmosphere by human activity.

It is often assumed that reducing the emission of SO_2 and NO_x will result in a corresponding change in the acidity of rainfall. However, the relationship between the emissions of acid precursors and the deposition of acids could be nonlinear, so that a considerable reduction in emissions might not result in a similar reduction in acid precipitation. More research is crucially needed to quantify the relationship between emissions and deposition.

Emissions of sulfur dioxide can be lowered by a variety of techniques. Sulfur oxide emissions from combustion sources can be decreased by switching from high-sulfur coal or oil to low-sulfur coal or oil, by cleaning coal prior to combustion, and by desulfurization of oil and flue gases. Physical cleaning of coal is a relatively low-cost technology for removing nearly half of the pyritic (inorganic) sulfur from coal before it is burned. Flue gas desulfurization technology is applicable to both combustion and noncombustion sources of SO_2. This technology can reduce SO_2 emissions from 50 to more than 90 percent.[27/] However, cost and limitations of available land for storage of wastes may limit the application of flue gas desulfurization technology, especially in existing combustion facilities.

Efforts to reduce emissions of nitrogen oxides have been limited primarily to the evaluation of technology to control these emissions at their source. Combustion modification technologies in general use today for stationary sources are lowering emissions by only 30 to 40 percent under optimum conditions. Demonstration tests of an experimental low-NO_x burner (the distributed mixing burner) began in 1980 and it is now coming into use. This new system has the potential to lower NO_x emissions by 70 to 80 percent. For mobile sources, combustion modification technology and catalytic control technology are in use to decrease emissions of NO_x, hydrocarbons (HC), and carbon monoxide (CO).

A spinoff of the low-NO_x burner technology is the possibility of combined control of SO_2 and NO_x. The technology is based on mixing limestone with coal before burning it in the low-NO_x burner. The concept has been demonstrated to be feasible in pilot scale tests, but more work is needed to perfect the technology and develop it for commercial use. If this technology is successful, SO_2 reductions of 50 to 70 percent and NO_x reductions of 50 to 80 percent might be possible at relatively low capital and operational costs.[28/]

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III. INFORMATION NEEDS

This part of the Plan identifies critical areas where more information is needed to improve our understanding of the phenomenon and consequences of acid precipitation. The questions and information needs posed herein must be addressed to provide an objective basis for establishing sound energy and resource management decisions, and cost-effective environmental protection policies. Answers to these questions are urgently required because:

1. There is growing national and international concern about acid precipitation and its effects;

2. Changes in energy use patterns could result in the emission of more precursors of acid precipitation.

3. Present information on acid precipitation is insufficient to support the development of reliable models capable of predicting its occurrence and assessing its consequence; and

4. A number of potentially irreversible effects of acid deposition have been postulated; but if, when, and where these may occur cannot be predicted with confidence.

Information needs are summarized here for each of nine research categories: natural sources, man-made sources, atmospheric processes, deposition monitoring, aquatic impacts, terrestrial impacts, effects on materials, control technologies, and assessments and policy analysis. Descriptions of the key questions to be answered in each of these nine categories provide the rationale for undertaking the specific research tasks outlined in Part IV.

A. Natural Sources

The identity and relative significance of the natural sources of airborne acidic materials and their precursors are major unknowns in the acid precipitation issue. Oxides of sulfur and nitrogen are known to be the principal acid precursors in many regions, but in some areas other substances, such as hydrochloric acid, carbonic acid, ammonia, iron and aluminum, also affect the acidity of wet and dry deposition. It has also been observed that, under certain conditions, organic acids may be important. However, the strengths and locations of the natural sources of these materials and their precursors have seldom been determined. The problem is made more difficult because most natural materials are emitted at low concentrations from wide areas, such as the oceans, tidal flats, forests, and geothermal regions. The acidity of deposited matter is a balance between acids and alkaline chemicals; thus it is necessary to determine alkaline contributions, such as from soils.

Natural emissions which contribute to acid precipitation can be divided into two categories--biogenic and non-biogenic. The main non-biogenic sources are geothermal emissions and wind-generated material, such as alkaline soil dust. Though some gases and particles are released to the atmosphere from areas of thermal springs, it is believed that erupting volcanoes are by far the most important sources in this category. Volcanic emissions of sulfur dioxide, hydrogen sulfide, nitrogen dioxide, and aerosols are considerable, though very sporadic in nature. Wind-generated, non-biogenic particulate matter, such as

sea spray, dust from soil erosion and gases, and particles from wildfires, also contribute to the chemistry of the final atmospheric deposition.

Biogenic sources are even less understood. A number of acid precipitation precursors of biological origin have been identified, including hydrogen sulfide, dimethyl sulfide, carbonyl sulfide, ammonia, and possibly other sulfur and nitrogen compounds as well as volatile organic compounds (VOC). Preliminary studies of sulfur compounds emitted by natural sources indicate that, although these materials are much smaller in amount than local or regional industrial emissions, they may be important globally. The importance of acid-forming nitrogen compounds from natural sources is largely unknown. To assess the importance of natural sources, it is necessary to know:

1. The characteristic emission rates and the geographical and temporal distributions of natural precursors of acid deposition;

2. The nature of the physical and chemical transformations that convert these natural precursors into the acidic materials that are deposited; and

3. The sources and emission rates of alkaline substances, such as wind-blown soils and ammonia, that play important regional roles in neutralizing acid deposition.

B. Man-Made Sources

Acid precipitation is formed as a result of complex interactions between acidic, alkaline, and neutral air pollutants. The principal man-made sources of these pollutants are particles and gases emitted by combustion of fossil fuels. Among the air pollutants identified as playing important roles in forming acid precipitation are sulfur dioxide (SO_2), oxides of nitrogen (NO_x), sulfates, chlorides, volatile organic compounds (VOC), and fine particulate matter. The principal sources of these pollutants are electric utility, industrial, commercial, and residential boilers and heaters, and internal combustion engines used by automobiles, trucks, airplanes, and other vehicles. Industrial processes such as metal smelting and chemical manufacture also are sources of these pollutants.

Man-made emissions of pollutants of interest, such as SO_2, NO_x, VOC, and fine particulate matter have been identified as the most likely precursors of acid precipitation in the U.S. To evaluate their importance and the importance of other pollutants of interest, several key questions must be answered for the historical, current, and future time periods as appropriate. These questions include:

A. Which industries or activities are the major sources of each pollutant of interest?

B. What is the geographic location of the major sources of these pollutants of interest?

C. What are the major characteristics of each emission source?
   1. Geographic differences in emission characteristics
   2. Temporal differences in emission characteristics
   3. Differences in operating characteristics between regions and during different time periods

4. Characteristics of major control technology options

D. How many tons of each pollutant of interest are emitted from each source or source category in each region during each time period?

E. How will each major source respond to different government policy options? (In conjunction with Task Group I)

C. Atmospheric Processes

The paths of acidic, alkaline, and potentially-acidic airborne materials from their sources to final deposition are complex and not fully understood. Three processes -- atmospheric transport, chemical and physical transformation, and removal or deposition -- determine the form and location of acid deposition. To date, scientists have had only limited success in describing these three atmospheric processes. Meteorology, chemistry, and aerosol and cloud physics are among the many disciplines used to investigate these interactive processes.

The atmospheric transport and dispersion processes can be defined as the purely mechanical movement of materials by the wind. The movement of even an inert tracer, such as a balloon released into the atmosphere, generally follows a very complicated path. Scientists use mathematical transport models to attempt to follow these complex motions. A number of these models have been developed to attempt to predict the distributions and atmospheric concentrations of SO_2 and sulfate ($SO_4^{=}$); models for NO_x are not yet available. SO_2 emissions data and meteorological data are used in several regional scale air pollution models to calculate monthly, seasonal, and annual atmospheric concentrations and depositions of SO_2 and $SO_4^{=}$. These models suggest that deposition in any one region may originate not only within that region, but also in neighboring and more distant regions. The relative importance of wet and dry deposition fluctuates strongly as a result of variations in meteorological and land use conditions. It is important that models consider a sufficiently large geographic area and a representative range of meteorological conditions to support their general applicability. If models are to readily lend themselves to understanding processes, a much greater focus must be placed on simulating day-to-day and storm-to-storm variations.

Chemical and physical transformation processes affect atmospheric residence times of pollutants, the chemical nature of deposited matter, and the relative importance of wet and dry deposition processes. In recent years, there has been a substantial increase in research on regional acid precipitation phenomena and on chemical reactions between pollutants and atmospheric water in both the gaseous and liquid phases. However, there are still major questions as to what mechanisms and reaction rates are responsible for gas-phase oxidation of sulfur compounds. Photochemically induced free radical pathways are currently suspected of being the primary contributors, but these processes are complex and incompletely understood. Therefore, the basic characterizations of oxidation rates for sulfur compounds in the atmosphere are subject to considerable uncertainty.

A significant understanding of the chemistry of volatile organics and nitrogen oxides in polluted atmospheres as it relates to photochemical oxidants has evolved over the past twenty or so years. Though past emphasis has been on

oxidant production and distance scales of the order of 100 km, this work provides a foundation for mechanism development and future research to determine the rate of acidic nitrogen production in the atmosphere.

Also of special interest are the actual mechanisms of scavenging and removal that take place in and below clouds. The wide range of processes such as cloud nucleation, capture of particles and absorption of gases by cloud droplets, and cloud lifetimes must be better understood. These mechanisms are also important during periods of no precipitation and may affect the dry deposition processes.

The ultimate question regarding atmospheric transport, transformation, and removal is "What is the atmospheric link between the emission of pollutants and acid deposition?". To construct models that can be useful to decision-making concerning acid precipitation, more must be known about:

1. The way in which wind and turbulence fields control long-range transport and dispersion. This includes more accurate parameterization of vertical and horizontal mixing and wind shear, cloud venting (vertical transport out of clouds), and topography.

2. The accuracy of present models for describing trajectories for predicting atmospheric transport. Meteorology, topography, and data scarcity in both space and time all serve to limit the accuracy of present trajectory estimates by unknown amounts.

3. The nature and rate of chemical changes that may take place during the transport of pollutants, especially the changes of SO_2 and NO_x into strong acids. The rates of these transformations as influenced by the amount of sunlight, atmospheric water content, temperature, concentration of reactive radicals and organics, and the quantity and form of particulate matter in the air.

4. The physical-chemical behavior of air pollutants in clouds. Other important uncertainties are the rates of incorporation of both gases and aerosols within raindrops and snowflakes (hydrometers). The rate of transformation of dissolved pollutant mixtures in clouds and the influence of this rate resulting from the presence of dissolved metals, such as Fe and Mn, and oxidants, such as O_3 and HO_2.

5. The rates of removal of pollutant gases and aerosols by raindrops and snowflakes. The influence of characteristics of the aerosols (size and shape) and hydrometers on the rate of deposition. The role of ion equilibbrium and pH considerations in the rate of scavenging of gases and aerosols by hydrometers. The influence of the physical properties of the terrain, vegetation, atmospheric winds, and aerosol and gas properties on dry deposition.

6. The transfer of acid precursors from the mixed layer by convective cloud venting. Acid precursors may be deposited locally due to local scavenging or transported and transformed over long distances before being scavenged. This material is influenced by different transport processes than those in the mixed layer and generally reaches different receptor locations.

Convective clouds can vent acid rain precursor pollutants out of the mixed layer. These clouds can either yield acidic rain if scavenged in local precipitating systems, or undergo long-range transport and transformation, before eventual scavenging by other precipitating systems. Transport bookkeeping is complex because cloud layer material generally reaches receptor locations different from those involved in mixed layer transport. The impact of this process will depend on the strength, duration, and areal extent of the venting region, all highly variable. The dynamic feedback that can occur between the convective ensemble and the meso/synoptic weather patterns adds additional complexities. Research to understand, and methodologies to incorporate cloud processes are essential for an adequate assessment of transport for source/receptor problems. This applies to both statistical and event approaches.

An improved understanding of the processes of atmospheric transport, transformation, and removal, and the validation of models that describe these processes can be obtained by analyzing the spatial and temporal patterns of wet and dry deposition measured in various regions of North America. Finally, little is known about very long-range, hemispheric, or global transport of man-made or natural acidic substances.

As acid deposition models are improved, they can help answer the following questions:

1. How much can acid deposition be reduced by attainable reductions in man-made emissio s? In which regions of the country should emissions be reduced to cost-effectively protect sensitive resources downwind?

2. How much of the acid deposition in Canada and in the U.S. originates from man-made emissions in the other country? What is the contribution of North American pollution to acid deposition in other countries, and vice versa?

3. What is the accuracy of acid precipitation models in the prediction of patterns of acid deposition and seasonal and year-to-year variability over the U.S.? What parameters most influence the accuracy of these predictions?

4. What is the degree of interaction among different pollutants (gaseous and particulate) emitted from the same or adjacent sources? Will, for example, gains achieved in acid deposition through SO_2 control be offset, to some degree, by an increase in nitrate formation and acidity? Are certain pollutant mixes, resulting from the collocation of different stationary sources, to be avoided due to their particularly adverse impact on acid formation and deposition?

D. Deposition Monitoring of Acid Substances

The chemical composition of atmospheric deposition in this country has not been measured systematically over periods long enough to permit adequate time-trend analyses. Monitoring networks established in the past have acquired some useful data, but all have been dismantled after relatively short periods of operation or have been too limited in geographic extent to produce a nationwide picture. There is also insufficient information on data collected by these networks to permit establishing sample validity, data quality, or

other parameters of quality assurance. As a result, there is great uncertainty about composition and trends of atmospheric deposition in the U.S.

A large-scale monitoring network was activated in the U.S. in 1955, but was discontinued after about a year of service. In 1965, a similar network was put into operation by the Public Health Service (PHS), and later the National Center for Atmospheric Research (NCAR). Although the PHS/NCAR network was abandoned after six years, a small number of its stations were retained as part of the World Meteorological Organization (WMO) network that is currently maintained by NOAA and EPA.

At present, seven major networks in the U.S. and one in Canada collect data on precipitation chemistry. The U.S. networks include USGS, NOAA-EPA-WMO, DOE-EPA-MAP3S, NADP, EPRI, TVA, and EPA Great Lakes. In addition, several state and university research networks are operational. All of these networks collect samples of wet precipitation. Each network was started for a different reason; e.g., the Electric Power Research Institute (EPRI) network was started to determine the contribution of power plants to atmospheric sulfur loading, whereas the EPA Region V network was initiated to determine the deposition of atmospheric pollutants into the Great Lakes. Samples from all existing networks are analyzed for major cations and anions. In many networks, samples are collected weekly or monthly, but in the EPRI and DOE-EPA-MAP3S networks, samples are collected from individual rain or snow storms (event sampling).

Present networks have the following limitations:

1. Many use different analytical laboratories and different methods of analysis, so their results are not always comparable. Only a few sample sites have been selected by using rigorously defined siting criteria;

2. Additional quality assurance is needed for the field and laboratory operations of all networks. Additional training of personnel would improve sample collection procedures;

3. Most sites are in rural areas of the northeastern or north-central states. In the western U.S., where future energy development could take place, and in urban areas, where materials damage is most common, there are few collection sites;

4. Monitoring techniques and strategies used by scientists of the U.S. and other countries may be inconsistent;

5. Methods for sampling dry deposition are inadequate; and

6. Few sites are equipped to gaseous pollutants and aerosols, or to provide adequate meteorological data.

In light of prior experience, major studies have been made of the precipitation monitoring needs in the U.S. by three organizations: a committee impaneled by the Federal Interagency Coordinating Committee on Water Data, the National Atmospheric Deposition Program, and EPA. A consensus has emerged from these studies and more recent discussions by the Task Group on the deposition monitoring of the Interagency Task Force on Acid Precipitation. This consensus may be summarized as follows:

1. A nationally coordinated, long-term program of wet and dry acid deposition monitoring is needed in the U.S.;

2. A program of deposition monitoring must consist of closely linked networks, and must be operated by scientists actively engaged in research on the environmental effects of atmospheric deposition;

3. Many different federal, regional, and state organizations have important needs for high-quality acid deposition information;

4. No single agency has the combination of mission, expertise, and resources to develop and manage an adequate national monitoring program with a diversity of objectives;

5. Adequate methods for the proper collection and analysis of dry deposition have yet to be developed; and

6. Mainly for reasons 1, 3, and 4, (above), a consortium of scientists from different federal and state agencies and universities will be needed to design, operate, and maintain an adequate monitoring program for the U.S.

Table 1 shows the three general types of federal monitoring networks needed and their characteristics. The efforts of existing networks will be carefully integrated, coordinated, and augmented, when necessary, to provide three distinct types of information:

1. Global trends in atmospheric deposition -- Long-term measurements of changes in the chemistry of wet and dry acid deposition should be made through a Global Trends Network (GTN) consisting of 10 to 12 selected sites in the U.S. and its Trust Territories. GTN sites should be remote from pollution sources and should be chosen so that data collected will represent global background values. The sites maintained by the U.S. should be selected jointly with other nations of North America and around the world to ensure that geographical and temporal trends in deposition of major anions and cations, toxic metals, and selected organic compounds can be monitored globally. This GTN should be coordinated with and through the World Meteorological Organization.

2. National trends in atmospheric deposition -- Long-term measurements of changes in the chemistry of wet and dry acid deposition should be made through a National Trends Network (NTN) consisting of approximately 100-150 background sites in all regions of the continental U.S. and Alaska. The sampling sites should be relatively remote from localized sources of pollution in order to define regional differences in deposition due to variations in the composition and movement of major air masses or to the general nature of contributing emission sources. Thus, the NTN would not only detect general regional differences in deposition but would also provide information on differences in the nature of deposition due to various source types. Specific siting criteria and operating procedures will be developed through the Task Group planning process, but the sites will generally be established for continuing operation, where possible, in connection with long-term research projects. The NTN will provide a long-term record of geographical and temporal variations of the major anions and cations in wet and dry deposition, and periodic measurements of toxic metal ions and selected organic substances.

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NETWORK	TYPE OF LOCATION	SITE LONGEVITY	SAMPLING FREQUENCY	PURPOSE	PRESENT NETWORK	NUMBER OF PROJECTED SITES
GLOBAL TRENDS NETWORK (GTN)	Remote	Greater than 20 yrs	Weekly or Event	Inter-continental transport & long-term trends	NOAA/EPA WMO	12
NATIONAL TRENDS NETWORK (NTN)	Relatively remote from identifiable point source influences	10 yrs to over 20 yrs	Weekly	Long-term trends and detection of chemical differences due to general source types	NOAA/EPA/WMO/DOA, (NADP)/USGS/DOE	100-150
RESEARCH SUPPORT NETWORK (RSN)	Special study site	Variable	Variable, event	Determination of cause/effect relationships & reasons for short-term variations in deposition chemistry	MAP3S (EPA-DOE)/ EPA Regions/ Urban Hydrology (USGS)/TVA/ EPRI/DOA, (NADP)	Variable 12

TABLE 1.

Atmospheric deposition monitoring networks and their characteristics

3. Specialized information in support of research -- Research Support Networks (RSN) for gathering information on such subjects as short-term variations in deposition chemistry, the relationship between meteorological conditions and deposition chemistry, and the suitability of sampling methodology and instrumentation, as well as for collecting data for verification of atmospheric deposition methods, should be operated for limited periods of time. These short-term networks should be organized and managed separately from the National Trends Network, but their design and methodology should be coordinated with that of the NTN.

The major objectives of the Global and National Trends Networks will be to measure seasonal, annual, and longer period trends in acid deposition in the states and regions of the U.S. These measurements would be compared with trends for similar periods in other nations of North America and the world. The data can be used for a variety of purposes, such as validation of transport models, estimation of exposure to acid deposition, decisions on land and water management practices, and determination of the effectiveness and costs of emission control strategies. The present NADP, NOAA-EPA-WMO, TVA, and DOI networks will serve as the foundation for further development of the National Trends Network.

E. Aquatic Impacts

Impacts on aquatic resources should be considered under two topics: first, the chemical alteration of water quality, including groundwater, drinking water supplies, streams, and lakes; and secondly, the effects on the species and populations that make up biologically productive components of aquatic ecosystems.

Water Quality

Studies comparing recent water quality data with those of 25 or 50 years ago show lakes and streams in certain remote regions now have lower pH and alkalinity, and higher sulfate ion ($SO_4^=$) and aluminum concentrations. These changes appear to be greatest where acid deposition has been high and are not observed under comparable land use practices where acid deposition is low. However, great differences exist from one watershed to the next, indicating that the surrounding bedrock, soils, residence time of rainfall/runoff in the watershed, and vegetation have a profound control over the effects observed. Thus, information on water quality effects from acid deposition would be closely related to that on soil and watershed, as described in the Terrestrial Impacts Section.

The principal questions related to water quality alterations are believed to result from deposition of the ions H^+, $SO_4^=$, NO_3^-, and NH. These questions include the following:

1. What are the trends of sulfate, nitrate, ammonium, hydrogen ion, and alkalinity concentrations in shallow groundwater and in streams and lakes? Are there unique water monitoring programs in the acid deposition regions that already provide quality-assured records on recent trends? Can quality assurance procedures be extended from the atmospheric deposition program to water quality effects monitoring, including measurements of watershed influences?

2. Since nitrogen is a limiting nutrient in some aquatic systems (more so than sulfur), what is the fate of nitric acid and ammonium ion deposition in watersheds? Under what conditions might nitric acid and ammonium ion inputs function and contribute to surface water acidity?

3. What factors in the surrounding soils, bedrock geology, and patterns of weather and climate make lakes or streams vulnerable to (or tolerant of) acid deposition? What is the relative contribution to lakes and streams of hydrogen ions from precipitation, runoff, and subsurface flows? Can existing data or field responses and information on processes be used to develop predictive models of watershed and water quality response?

Because of the potential human health impacts of acidification on drinking water quality, we also need answers to the following:

1. Have pH and heavy metal concentrations and recalcitrant organics such as DDT and PCB's in surface and ground sources of drinking water changed over time? How extensive are the effects of acid deposition on septic field micro-organisms and decomposition processes? How many home, livestock, and municipal drinking water systems are affected by changes in water chemistry, and how large are the populations they serve? Where are these water systems?

2. What methods do we have for treating drinking water to reduce its content of acidity or heavy metals? Can the acidity of drinking water systems be safely adjusted by liming or other treatment?

Biological Productivity of Aquatic Systems

Major biological changes in natural resource systems that appear to be attributable to acid deposition are documented primarily for freshwater systems. The decline of fish populations in certain areas of Europe and North America is the most evident impact of acid deposition. So far, concern has centered around the complete elimination of fish from affected lakes and streams, and this response seems to be a current de facto definition of injury.

A variety of other biological changes, including reduced energy fixation, decreased species diversity, and reduced organic decomposition, occur in aquatic ecosystems with much less acidification than is required to eliminate all fish. However, these other changes are known only qualitatively. Essentially, no quantitative studies on the effect of acidification on population dynamics are available for species other than fish. While there is little doubt that high concentrations of H^+ and aluminum (originating from watershed acidification) are responsible for the complete elimination of fish in the most heavily impacted waters, interactions of fish with their altered food supply in the pH range 5-6 remain unstudied.

The principal questions related to these biological impacts of acid precipitation are:

1. How many lakes have been chemically altered by acid deposition? How many of these now have declining fish populations? Are either the chemical or biological changes in lakes and streams reversible or irreversible? How many more lakes and streams are vulnerable or tolerant to acid deposition?

Where are they? Will these lakes be acidified if atmospheric emissions remain the same? If the emissions increase? If the emissions decrease? What are the economic consequences of declining fish resources and associated recreational activities? Can we predict the time when irreversible damage will occur?

2. Using available records on the chemistry of streams and lakes and on changes in fish populations, is it possible to develop predictive models or simple measurements for estimating the tolerance of these resources to defined levels of acid deposition? Can these models be validated? If validated, will they be appropriate aids in resource protection decision processes?

3. How are key aquatic biological processes altered by acid deposition? What are the effects of aluminum and H^+ on primary production, decomposition, and nutrient cycling? How are trophic dynamics altered, especially at intermediate levels of acidification (pH 5-6)?

4. What are the effects of H^+, aluminum, pesticides, and other metals on food web organisms? Are acute seasonal and episodic acidification events (such as occur during snowmelt or intense rainfall) of greater importance in altering community dynamics than other natural episodic events, long-term acidification, and natural evolution?

5. What corrective procedures can be used to protect lakes and streams against the effects of acid deposition and to restore affected habitats? What are the comparable costs and benefits identified with various measures for mitigating these effects?

F. Terrestrial Impacts

Altered precipitation chemistry and acidic deposition has the potential to affect crops, forest trees, and range vegetation directly. It also has the potential to alter soil chemistry and thereby influence plant growth. Thus, information on terrestrial impacts must cover the complex interaction between direct and indirect effects of acid deposition (SO_x and NO_x), and must distinguish these effects from the known impacts of related air pollutants such as ozone.

Forest Trees and Range Vegetation

Forest trees and range plants may be influenced and, in turn, influence acid deposition for several reasons: (a) they are long-lived plants and thus subject to long-term as well as short-term responses to acid deposition; (b) forest trees present very large surfaces for interception of atmospheric deposition; (c) forest trees and range plants usually grow on lands in which nutrients from sources other than atmospheric deposition are scarce and where fertilization and liming are rare; and (d) forests and rangelands include considerably more diverse groups of organisms than agricultural lands.

Acid rain simulated in laboratory and short-term field experiments has induced a variety of biological effects on forest trees. However, significant economic damage to forest and range plants by naturally occurring acid rain has not yet been demonstrated. The main questions that arise in this area are:

1. What are the beneficial or injurious effects of acid deposition on the growth of forest and range plants? Do the nutrients contributed by acid rain affect forest and range productivity? If so, how and to what extent? Which biota are affected?

2. Does acid rain inhibit reproduction and regeneration of forest and range plants? At what stages of growth are plants possibly vulnerable to wet and dry deposition of acidic compounds? Are the viability of pollen, the onset of fertilization, the germination of seed, and the establishment of seedlings affected by acid rain?

3. Can acid rain accelerate leaching of nutrients from leaves and other foliar organs? Does acid deposition cause premature defoliation or other metabolic problems that may lead to decreased productivity and/or quality of wood? Does acid deposition alter the mix of hardwood and softwood trees in forests or the mix of plant species in rangelands?

4. Does acid rain affect the susceptibility of forest trees to other air pollutants or to insects, bacteria, viruses, fungi, and related causal agents? Does it have direct effects on insects and related forest pests?

Indirect processes such as nutrient stripping and metal toxicity also require study. Questions here include:

1. How much acid precipitation can various ecosystems tolerate? Does the susceptibility of hardwood forests to acid rain differ from that of coniferous forests? What is the economic cost of altered productivity for forests and range vegetation? What are the possible contributions of modified forestry practices to acidification?

2. What can be done to protect or mitigate the effects of acid deposition on forest and range resources? What are the comparative effects of dry and wet deposition?

Agricultural Crops

Changes in the growth and development of agricultural crops have been demonstrated in controlled laboratory and field experiments using simulated acid precipitation. However, economic damage caused by naturally occurring acid rain remains to be documented. Studies have shown that simulated acid rain causes accelerated erosion of protective waxes, decreased nodulation and fixation of nitrogen by legumes, and possible interference with fertilization and production processes in various cultivated plants.

Simulated acid rain also has been shown, in controlled laboratory and field experiments, to affect some processes in the growth and development of agricultural crops. Although economic damage by naturally occurring acid deposition has not yet been established, the potential for damage warrants intensive research to provide answers to the following questions:

1. What crops are affected by acid precipitation and at what pH? What are the comparative effects of wet and dry deposition? What are the effects on yield and quality of food, fiber, seed, and other plant products? In what geographic regions are plants affected most seriously? Are there any synergistic interactions with other pollutants such as ozone?

2. What are the dose-response relationships among major components of atmospheric deposition (including oxidants) and various crop plants under varying soil, climatic, and growth stage conditions? What are the current and future consequences of continued atmospheric deposition on the basic growth processes involved in food, feed, and fiber crop systems? What are the potential contributions of agricultural practices to acidification? What are the economic impacts? What mitigative measures are possible and what are their economic advantages?

3. Are crop problems with diseases, insects, and weeds exacerbated by acid deposition? If so, how and to what extent? Does acid rain alter the susceptibility of crops to injury by other air pollutants?

4. To what extent can acid deposition influence the uptake and accumulation of toxic metals and other toxic substances in crops?

5. Which crops are significantly benefited by acidic deposition of nutrients and sulfates and under what nutrient stress conditions?

Soils

The effect of acid deposition on natural soil processes in humid regions, including the retention or mediation of substances transferred from the atmosphere to soil solution, ground water, and streams must be assessed. Chemical reactions which may alter the productivity of unmanaged soils by leaching nutrients, by decreasing the ion exchange capacity of the soils and watersheds, by increasing the solubility and movement of toxic elements in watersheds, and by causing changes in soil biota require study. In some agricultural and managed forest areas, the effects of acidification may be controlled by application of soil amendments such as ground limestone. However, some agricultural practices, such as the use of ammonium and urea forms of nitrate fertilizers, tend to acidify the soil, especially the top horizon in no-till and minimum-tillage cultivation.

Natural vegetation-soil systems are a basic interface between atmospheric deposition and the geological substratum. Better understanding is needed of the natural processes affecting hydrogen ions in soils, the direct and indirect effects of acid deposition on these processes, and whether there is a tendency for dry and wet deposition to retard or accelerate soil weathering, the leaching of nutrients, and the decomposition of organic matter.

Forest soils often are less fertile than agricultural soils, so forest growth could be more dependent upon atmospheric contributions of nutrients than are plants grown in cultivated soils. Acid rain may be responsible for altering clay minerals, promoting soil erosion by weakening surface vegetation, reducing cation exchange capacity, and accelerating natural acidification and the associated leaching of soil nutrients.

Because of these uncertainties, answers are needed to the following questions:

1. What soils or watershed systems are most vulnerable to deleterious changes because of acid deposition? Where are they located? How rapidly can important changes occur? Are soils being degraded and is water quality being affected by nutrient impoverishment, increased availability of

certain toxic metals, accelerated degradation of soil minerals and structure, or by all of these mechanisms? A more complete understanding of acid generation in natural systems is needed to properly evaluate the influence of acid deposition.

2. What are the beneficial or injurious effects of acid deposition on soil fertility and on the growth and productivity of forests and agricultural crops? What changes are occurring in the ability of soils to support regeneration and growth of forest vegetation? Do acid inputs increase leaching rates of nutrients more than they increase rates of nutrient release by weathering?

3. Does acid precipitation influence soil microbiological processes such as nitrogen and sulfur transformations, nitrogen fixation, decomposition of organic materials (especially forest litter), and other mineral transformations? Can we predict accurately the present and future effects of acid deposition on the fertility or chemical toxicity of soils? How does this response change with climatic variations and fluctations in the quantity and quality of acidic precipitation?

4. Does acid rain induce irreversible changes in the physical, chemical, and microbiological characteristics of soils? If so, do these effects extend to whole watersheds, irreversibly altering water chemistry?

5. What is the economic impact of the effects of acid rain on soils and watersheds? What is the cost of liming materials to neutralize the effects of acidic precipitation on soils in different regions?

C. Effects on Materials and Cultural Resources

Any assessment of the impacts of atmospheric pollutants on man-made structures must take into consideration that not all construction materials are durable, even in the absence of atmospheric deposition. Hence, it is important to differentiate between normal expected weathering and accelerated deterioration attributable to acid deposition.

To evaluate the magnitude of materials damage and to develop priorities for policy and management decisions, we need to know:

1. What materials and structures are most affected by acid deposition in urban and rural environments? By what mechanisms and at what rates are materials affected?

2. What is the economic effect of acid deposition on construction materials? What are the costs of replacement, restoration, maintenance, and miscellaneous expenses connected with damage caused by acidity?

3. What are the changes to materials caused by air pollutants and those caused by acid precipitation? Are there additive or synergistic interactions between acid rain and other air pollutants? What are the estimates of wet and dry chloride deposition and in its combination with nitric and sulfuric acids in corrosion processes? What are the estimates of air pollutant loadings on susceptible structures as influenced by deposition from local and distant sources?

4. What mitigative measures, such as increased cleaning cycles, protective coatings, or impregnations, are available or could be developed for the protection of various materials? What are the costs/benefits of such measures? What portion of such costs are attributable to acid deposition as opposed to other pollutants and natural decay?

5. Are irretrievable cultural and historic resources at risk?

Examination of the corrosion or deterioration of materials is a well-established discipline; however, the dose-response relationship between atmospheric pollutants and material corrosion is poorly documented, and appreciation of the influence of microenvironmental parameters, such as surface variation and structural shielding from exposure, requires clarification.

Future work on metals corrosion or stone deterioration must delineate the following specific factors:

1. Deposition ingredients that are active on selected construction or building materials (e.g., the impact of ammonia on the corrosion of metals);

2. Effect of constant background levels of chloride ions and carbonyl sulfide on the corrosion of materials;

3. The role of aerosols or particulates in material degradation;

4. The role of sulfate ion in the corrosion of materials as compared to the role of SO_2;

5. Effects of episodic events compared to continuous moisture and temperature cycles;

6. Effects of biological activity, particularly on building materials containing carbonate species, or on surfaces exposed to carbonate-containing dusts;

7. Dose-response relationships for a range of corrosive agents and surfaces, determined in field and controlled environments, and in laboratory models;

8. The relative importance of wet/dry-deposit pollution in the subsequent corrosion process;

9. The role of electrophoretic effects produced in porous stone by the absorption of strong electrolyte solutions; and

10. Neutralizing agents that may be available and have not yet been monitored in precipitation network studies.

H. Control Technologies

Controls to reduce emissions of acid rain precursors, sulfur dioxide, and nitrogen oxides, may be either passive or active. Passive control of the acid precursors includes techniques such as conservation and adjusting the order in which steam-electric boilers are brought into service whereby those with highest SO_x or NO_x emissions are used least or at times of low impact. Active controls involve both the use of control technology and a switch to the use of

less-polluting fuels. To identify the proper mix of control techniques, we need to know:

1. The projected annual contribution, by both stationary and mobile sources, of SO_2 and NO_x emissions for each region under consideration;

2. The cost associated with reducing emissions of sulfur and nitrogen oxides from mobile and stationary sources using state-of-the-art control technology;

3. The most cost-effective emission control technologies now in existence that can be used with existing facilities and the projected costs of emerging control technologies; and

4. The projected costs of other active and passive control measures.

Although the preceding discussion of control technologies is of SO_2/NO_x control only, it is important to note that control of other pollutants such as oxidants could be important in reducing acid precipitation and its effects.

I. Assessment and Policy Analysis

The fundamental purpose for carrying out all acid deposition research is to provide a basis for decisions at the federal, state and local levels. Decisions must ultimately be made on whether and/or how to manage man-made sources of acidity and/or to mitigate its adverse effects. Assessment and policy analysis activities serve to focus scientific research upon policy issues and to organize research results into a framework which allow these policy decisions to be made. Assessments are summaries of available scientific information and uncertainty to establish the need for action and/or further study. Policy analysis is the formulation, comparison, and evaluation of alternative courses of action. Assessment of all aspects of the deposition of acidic and acidifying materials is required. This includes tracing of causal relationships from emissions through transport and deposition to direct and indirect effects on all sensitive receptors. Results of assessment activities will improve the comprehensive analysis of costs and effectiveness of alternative emissions control and mitigation strategies.

In order for assessment and policy analysis research to achieve its dual objectives of assisting research prioritization and reviewing and analyzing emission control and mitigation alternatives, the following activities are necessary:

1. Synthesis and assessment of current scientific knowledge on the degree, location, and significance of today's levels and expected future levels of the various adverse effects which could potentially result from acid deposition;

2. Synthesis and assessment of scientific knowledge about the distribution and composition of acidic deposition, the source-receptor relationships, atmospheric composition, and emission patterns. An improved understanding of existing source-receptor relationships and the possibilities of reducing acid deposition through the control of man-made emissions is needed;

3. Formulation of a range of emission control and effects mitigation strategies for comparative analysis;

4. Application of available data and analytical tools to the comparison of the strategy alternatives on the basis of cost-effectiveness and cost-benefit; and

5. Identification of research which could reduce uncertainties hindering the policy analysis process.

IV. RESEARCH PLANS

[illegible] described in this section are designed to meet the information [illegible] in Part III. More detailed descriptions of the planned research [illegible] developed by the Task Groups for each of the nine categories [illegible] (see Part V.B.3).

[illegible] is underway in many of the proposed areas of investigation. [illegible] deposition monitoring networks will have to be [illegible] a continuous and high quality record of temporal and geographic [illegible] the chemistry of wet and dry acid deposition.

The Task Force has agreed to the following criteria for assigning research task priorities:

Priority 1 - [illegible] research of the highest priority. Timely conduct of [illegible] is necessary to answer critical scientific questions [illegible] acid deposition. Each task investigates a crucial question where [illegible] similar research is underway. The economic or social value of [illegible] affected resource is high and the geographical area of [illegible] sensitive to or heavily affected by acid deposition.

Priority 2 - Research that addresses an important information need but is [illegible] than Priority 1. The phenomenon or geographical area to be [illegible] believed to be moderately sensitive to acid deposition. The economic [illegible] value of the affected resource is high.

Priority 3 - [illegible] research of less urgency than the work covered by Priority [illegible] geographical areas included are not likely to be [illegible] by acid deposition until well after 1990. The economic [illegible] potentially affected resource is moderate.

[illegible] assigned to the research tasks in this Plan may change [illegible] needs are identified. The Task Force will [illegible] priorities as necessary in future versions of the Plan [illegible] the National Acid Precipitation Assessment Program.

[illegible] the proposed research tasks are identified:

[illegible] with direct involvement in the specific task and [illegible] that are integral components of the task.

[illegible] directly involved in the task but with activities [illegible] knowledge or other input relevant to the research [illegible]

[illegible] are arranged in the following format: a description [illegible] of the research approach; the relative priority [illegible] and indirectly contributing agencies involved [illegible] proposed starting time and duration of the proposed [illegible] where work is already ongoing are identified by the [illegible] description. A summary table of these research [illegible] Appendix A.

A. Research on Natural Sources
(Coordinating Agency-NOAA)

The occurrence of acid precipitation in regions extremely remote from anthropogenic activity suggests our current understanding of natural sources of acidic and pre-acidic materials may be grossly deficient. The following specific research efforts will be undertaken to increase our understanding of both short-term and long-term changes in materials of natural origin that contribute to acid precipitation.

1. Analysis and Assessment of Natural Sources of Acid Deposition

This task will seek to identify and to determine the locations and strengths of natural sources of acidic and pre-acidic materials contributing to acid precipitation. There are already indications that organic sulfur compounds like carbonyl sulfide (COS) and carbon disulfide (CS_2) can be oxidized to sulfur dioxide. Special measurement techniques will have to be developed to search for new pre-acidic chemicals in the air. The sources are likely to be biogenic so that the search must be conducted on both land and oceans. This research will include examining possible sources of pre-acidic materials released by agriculture and estimating changes in release rates related to modifications of agricultural practices.

Quantitative assessment of the source strengths is difficult and will probably have to be approached in stages: establishing the existence of relevant chemicals in air; estimating the flux from other information; measuring, insofar as possible, the local source strengths; and extrapolating the local findings to regional or global emissions. The research will also involve specialized measurements of acid deposition in regions very distant from man-made sources and identifying the source of the acidic materials. A search will be made for airborne acidic and pre-acidic materials in parts of the atmosphere remote from man-made sources, like the upper troposphere and lower stratosphere, or in Antarctica. Priority 1; Participating agency - NOAA; contributing - EPA, DOE, DOI, NASA, NSF; Five years beginning in 1981.

2. Case Studies of Neutralizing Materials in the Atmosphere

Precipitation deposits alkaline as well as acidic components, and the acidity level results from an interaction of the two. Thus, a study of alkaline as well as acidic substances in air and water will be undertaken. The characteristics of the alkaline dust will be determined both in the air and at its likely sources. This includes sampling relevant airborne particles and the probable sources of the atmospheric dust, such as the arid Southwestern landscape and the industrial emissions. This task will document the nature of alkaline materials present both in air and precipitation in order to help guide studies of the sources of these materials.

If it is found that the bulk of the airborne alkaline dust is derived from arid regions, then the specific source areas will be identified. This research will also involve attempting to estimate how the source strengths of the alkaline material may change due to man's activities from both industrial growth and land use changes. Chemical analyses of atmospheric aerosols, gases and precipitation, air measurements at aircraft altitudes, and meteorological trajectory analyses will be used to trace likely regions of origin. Studies on the buffering action of the airborne alkaline material will also be

undertaken. Priority 1; Participating agency - NOAA; Contributing - EPA, DOA, DOE, NASA, NSF, TVA; Five years beginning in 1981.

B. Research on Man-Made Sources
(Coordinating Agency-DOE)

The following research programs will help answer the questions posed about man-made sources in Chapter III, Section B. In general, this research will provide estimates of past, current, and potential future national and regional emissions of pollutants of interest.

1. Inventories of Current Emissions of Pollutants of Interest

Improved comprehensive estimates of North American emissions of pollutants of interest will be generated, maintained, and updated. These inventories will draw on existing data bases wherever possible with intercomparison and reconciliation of differences where more than one source of data exists for a pollutant of interest and source sector. SO_2 and NO_x inventories will be completed; the scheduling of inventory development for other pollutants, as well as the level of spatial and temporal disaggregation, will be established based on the needs of atmospheric modeling and other analyses and the availability of data. Priority 1; Participating agencies - EPA, DOE; Contributing - TVA; Nine years beginning in 1981.

2. Developing Models for Emission and Economic Analysis

Work on model development will incorporate improved capabilities to forecast regional economic activity and population shifts, consistent with national economic and energy forecasts. This information is required to determine potential future locations of major emitters of pollutants of interest.

A second part of the model development task will provide detailed information on the geographic and temporal differences in the emissions characteristics of major sources of pollutants of interest. Differences in operating characteristics between regions and during different time periods, as well as the characteristics of major control technology options, will also be incorporated. This information is required to estimate emissions and emissions control costs.

The third part of the model development task will yield a series of mathematical models to simulate fuel competition, industrial plant operating decisions, emissions from major sources and associated emission control costs. These models will account for the effects of fuel supply and transportation systems, and will consider both economic and non-economic decision factors. In particular, these developments will improve our capability to anticipate the effects of government policies (including taxes, economic incentives, and regulations) on siting, fuel choice, plant retirement and other plant operation decisions in those industries which are major sources of pollutants of interest (e.g. major fuel burning facilities). These capabilities also will enhance our ability to identify and evaluate cost-effective national and regional strategies for reducing acid deposition precursors. Priority 1; Participating agencies - EPA, DOE; Contributing - TVA; Eight years beginning in 1982.

3. Baseline Emission Projections

Using available modeling capabilities and data bases, one or more baseline projections of future emissions of key pollutants of interest will be produced. These projections will be based on assumptions about future economic and energy supply conditions and the absence of specific policy initiatives to control acid precipitation precursor emissions. These projections will be updated periodically as assumptions are refined or new projection capabilities are developed. These projections will provide a reference against which to evaluate the future costs and benefits of control strategies. Priority 1; Participating agencies - EPA, DOE; Contributing - TVA; Eight years beginning in 1982.

4. Analysis of Historic Emissions Trends

The feasibility of producing estimates of emissions of pollutants of interest for time periods dating back up to 100 years will be investigated. Where available data will support such estimates and the expected accuracy of results justifies the investment of resources, estimates will be produced. Priority 2; Participating agencies - EPA, DOE; Contributing - TVA. Four years beginning in 1982.

5. Detailed Analyses of Factors Affecting Emissions from Man-Made Sources

In the characterization of source categories, various types of uncertainties will be identified which will require more detailed analyses of some of the major factors which influence the contribution of man-made emissions to acid precipitation. Frequently these analyses will be carried out in conjunction with other Task Groups; for example, an analysis of the expected retirement age for major energy facilities, coordinated with Assessment and Policy Analysis research efforts. Another example is the investigation of fingerprinting techniques to relate the deposition of a pollutant to its point source. Priority 2; Participating agencies - EPA, [illegible]; Contributing - TVA; Seven years beginning in 1983.

C. Research on Atmospheric Processes
(Coordinating Agency-NOAA)

To understand the role of atmospheric processes in acid precipitation, much research is needed to provide a broad range of information on the transport of pollutants, their transformation in the atmosphere, and their eventual deposition on the earth.

Transport

Among the key problems to be investigated in the area of physical transport of airborne acids and acid precursors are:

1. Research on Long-Range Transport and Dispersion

This research task will enhance our capability to calculate and predict the transport and dispersion of substances by air motions. It includes acquiring an adequate base of wind data for the U.S. and adjoining regions for use in the calculations of air motions. Through the use of inert tracers capable of being followed up to distances of at least 1,000 km from their release, a number of current transport problems will be studied

to: improve and validate trajectories and dispersion over flat terrain; understand and reconstruct air movements over irregular terrain (such as in the vicinity of mountains and coastal areas); and, determine the vertical as well as horizontal spread of puffs and continuous plumes.

It will be necessary to conduct tracer tests under a variety of weather conditions, seasons, and release heights. In recent years several suitable tracers have been developed and the present acid deposition transport task may be conducted with tracers released for other applications. The field work will contribute to the further development and improvement of models of transport and dispersion. Priority 1; Participating agencies - NOAA, DOI, EPA; Contributing - DOE, TVA, NASA, NSF; Five years beginning in 1982.

2. Determining Global and Regional Circulation of Acidic Materials

Because some of the chemicals and their precursors involved in acid deposition may have very long lifetimes, their global and regional dispersion takes on considerable importance. The observation of precipitation with low pH at locations remote from man-made sources of pollution suggests, although does not prove, global scale dispersion of acidic materials or regional, unrecognized natural sources. This task will improve the existing models of two and three dimensional transport and mixing. The chemistry and removal processes associated with acid deposition will be introduced into the transport models. Validations of parts of the models will use existing tracers, such as nuclear bomb debris and fluorocarbons.

Climatological precipitation patterns will be incorporated into the models to deal with wet deposition of acidic materials. Terrain types and climatological surface-wind speeds will be incorporated into the models in order to deal with dry deposition. The resulting models will be run with typical geographically distributed emissions of sulfur and nitrogen oxides to produce estimates of worldwide deposition of acidic materials. Priority 1; Participating agencies - NOAA, DOE, EPA; Contributing - TVA, NASA, NSF; Six years beginning in 1980.

Transformations

Rarely is a sulfate or nitrate injected directly into the atmosphere to produce an acid. Rather, during long-range transport complex chemistry occurs to create the sulfuric and nitric acids from their precursors. The existing models mainly use empirical relationships to approximate this conversion; the proposed research will help provide a better understanding of the actual processes, rates, and complexities of the conversion. The following projects are designed to increase our knowledge of chemical and physical transformations:

3. Investigating Chemical and Physical Transformations

The chemical and physical transformations that convert sulfur and nitrogen containing species into acid materials will be investigated by laboratory and field measurements, accompanied by chemical modeling studies. The laboratory investigations will focus on the reactions that involve key atmospheric radicals and oxidants like OH, HO_2, and H_2O_2, which are expected to play major roles in the formation of acids. These studies will

include gas-phase processes; gas-particle, gas-droplet, and particle-droplet; and liquid-phase processes. Many of these investigations will require the development of new measurement techniques. The reaction rates from these studies will be used in newly developed chemical models to relate precursors to acid concentrations. Field measurements of these quantities, as well as the oxidants, will furnish input and validation of the understanding of these chemical transformation processes. Priority 1; Participating agencies - NOAA, DOE, TVA, EPA; Contributing - NASA, NSF; Ten years beginning in 1980.

Removal

The final atmospheric process in the deposition of acid materials is their physical capture or scavenging by other particles, cloud droplets and precipitation. The following research tasks are proposed to investigate removal processes:

4. Research on the Scavenging of Particles and Gases by Clouds

The current empirical or quasi-empirical approach to precipitation scavenging will be replaced by a more realistic formulation of the way clouds and precipitation elements remove acidic materials from the air. A number of scavenging processes have been identified, such as inertial interception of small particles, molecular exchange of gases between air and water, and the nucleating action of certain particles. Studies will be made to determine which processes are important for clouds and which for falling droplets; and whether both, the liquid and solid state of water, are equally effective in scavenging or removal.

The techniques of study will include both laboratory and field investigation. When the research succeeds, an improved sub-model of wet acid deposition can be added to the transport and chemistry components. Priority 1; Participating agencies - NOAA, DOE, EPA; Contributing - NASA, NSF; Ten years beginning in 1980.

5. Improving Modeling Data Bases

To improve the usefulness of existing and future atmospheric models, additional data will be compiled for parameters such as wind-speed and direction, temperature, land-use patterns, and general air quality. Priority 3; Participating agency - DOE, EPA; Contributing - NOAA, TVA; Four years beginning in 1981.

6. Improving Computer Simulation

Much progress has been made in the prediction of long-term average air quality and deposition of sulfur compounds, but improvements are still needed. Modeling efforts must continually incorporate the results of laboratory or field experiments. Ongoing modeling efforts, specifically MAP3S, will continue to be supported as part of this task. Special problems in the development of regional deposition models must be solved; for example, composite models that integrate wet and dry deposition processes and other source receptor pathways need additional basic information on those factors available. The most important needs for improved model

development include: regional models for nitrogen oxides and nitrates; inclusion of more realistic chemistry, dry deposition and acidity distributions; episodic models; expanded geographical coverage; and added data on other acid forming species. Model development activities in this area must be closely coordinated with activities in other areas. Priority 1; Participating agencies - EPA, DOE, NOAA; Five years beginning 1980.

D. Deposition Monitoring of Acid Substances (Coordinating Agency-DOI)

The importance of establishing a long-term monitoring program cannot be overemphasized. Past experience in the U.S. and Northern Europe proved that the geographic extent of the acid rain phenomenon and changes in its intensity with time, can be determined only by means of a balanced, well-coordinated, and well-supported program. To achieve these monitoring goals, the following four areas will be addressed:

1. Continued Improvement and Evaluation of the Global Trends Network (GTN)

Information on global variations in precipitation acidity will provide a basis for understanding the pattern of acid precipitation in North America and the degree to which outside influences control that continental pattern. The existing sites in the U.S. and its territories that are included in the worldwide deposition monitoring network that is operated through the World Meteorological Organization (WMO) presently constitute a Global Trends Network (GTN). This network will be evaluated with respect to adequacy of number and location of sites and will be modified as needed on the basis of that evaluation. Conformity to WMO's requirements will be maintained. Network operations will be coordinated with those of the National Trends Network (NTN) so that all data from the two Networks will be compatible. Priority 1; Participating agencies--NOAA, EPA; Contributing--DOE; Ten years beginning in 1980.

2. Further Development of National Trends Network (NTN)

Federal agencies will continue present cooperative efforts to quickly implement a permanent and high-quality National Trends Network (NTN). All laboratory analyses, sampling methods, and siting protocols will be standardized. Expansion of the NTN into urban areas, energy growth areas, and other critical regions will be evaluated, but only if acceptable quality assurance protocols and relative permanence can be assured. This network will be closely coordinated with the GTN and with comparable networks in Canada.

The most extensive network for monitoring atmospheric deposition in the U.S. is operated through the National Atmospheric Deposition Program (NADP). This Federal-State program is carried out through the Cooperative State Research Service (USDA) and was organized before the creation of the Task Force or its predecessor the Coordinating Committee. It involves a large number of Federal, State, university, industry, and Canadian participants, including most of the member agencies of the Task Force. The monitoring activity is highly organized with respect to siting and operational criteria for sampling sites, analytical methodology, and data handling and storage. In order to take maximum advantage of this already multiagency monitoring operation, the Department of the Interior expects to make arrangements with NADP to coordinate operation of the NTN

under guidelines provided by the Task Group on Deposition Monitoring. Activities to be coordinated by NADP will include site operator training, collection and processing of samples, and data handling and storage. Although a large number of the monitoring sites in NADP are expected to be incorporated in the NTN, the two monitoring networks will retain their separate identities and lists of sites. Duplication of efforts will be avoided by close coordination between the Department of the Interior and the Department of Agriculture. Priority 1: Participating agencies--DOI, DOA, EPA, NOAA, TVA; Contributing--DOE; Ten years beginning in 1980.

3. Developing Methods for Sampling Dry Measurements

No satisfactory method is available currently for the routine monitoring of dry deposition. The problem of collecting representative samples is made difficult by the variety of mechanisms involved in the transport and deposition of airborne materials on surfaces, the low concentrations of chemical constituents in the dry deposition, and the effect of the surfaces themselves on the rates of deposition.

There are several approaches to measuring dry deposition which will be studied: relating the downward flux to the ground of acidic materials to their vertical gradient of concentration; correlation techniques that measure the upward and downward net transfer via vertical wind and instantaneous or integrated concentration measurements; and collection of acidic materials on artificial surfaces simulating the ground, water, vegetation, etc. Each of the techniques possesses merits and limitations. It is proposed to explore each of the possible approaches during the first year and then initiate work on the most promising methods during the second year. Equipment testing will be performed during the third year. Priority 1: Participating agencies--EPA, NOAA, DOE; Contributing--DOI, DOA; Five years beginning in 1982.

4. Expansion and Improvement of the Research Support Networks

A major effort will be made to coordinate research on all atmospheric chemistry and meteorological factors essential to building models for predicting acid deposition in various regions of the U.S. and Canada. A key part of this coordination will be the establishment of regional, semi-permanent research sites, at which specific acid rain problems can be addressed and whose role is, therefore, different from the larger-in-number and more-simply-instrumented monitoring sites. Testing and inter-comparison of newly developed instrumentation and detailed measurements aimed at model validation will be among the objectives of research site operation. Priority 1: Participating agencies--DOI, DOE, EPA, NOAA; Contributing--TVA; Ten years beginning in 1980.

E. Research on Aquatic Impacts
(Coordinating Agency - EPA)
Water Quality

The information needs on water quality effects from acid precipitation concern regional trends, factors affecting watershed tolerances, the chemistry of metal mobilization, modeling, and related dose/response relationships for watersheds, lakes, and streams, and the risk associated with effects on drinking water. Specific requirements include the following:

1. Monitoring National and Regional Water Quality

Just as the monitoring of national trends in acid deposition required carefully established sites and quality assured measurements, documentation of trends in the effects being expressed in water quality will require a coordinated national design. Monitoring of selected headwater lakes and streams will be conducted in cooperation with private research programs (e.g., the EPRI New York, Wisconsin and Tennessee studies) and the principal state and regional agencies responsible for surface and groundwater quality. The monitoring will utilize water chemistry measures relating to the potential success of fish populations and other biota. In addition to the water chemistry, factors to be documented should include: weather and acid deposition records; air trajectory data and the frequency of lightning (a natural nitrate production mechanism); soils, geology, and land use in the watershed and upwind areas; and watershed management trends that could affect the acid neutralizing and buffering capacity of the vegetation and soil. Early results of the NSF program on Long Term Ecological Research now focused around 10 sites nationally, should be used in standardization of measurement frequency and site characterization. Priority 1; Participating agencies - DOI, DOA, EPA, TVA; Five years beginning in 1982.

2. Determining Factors that Control Lake Susceptibility

Using data developed in the above task and other available information, attempts will be made to identify which factors (such as surrounding soil and vegetation, geological features, weather, and climate) contribute to the tolerance or susceptibility of watersheds and surface waters in various parts of the U.S. Analyses of these lake/environment relationships will also indicate the relative importance of hydrogen ions from precipitation and dry deposition, relative proportions of nitrate and sulfate inputs, soil-chemical processes, predominant vegetation, and bottom sediment characteristics. This information will be useful in identifying regions in which reduction in pollutant deposition could be of maximum benefit to water quality and associated aquatic biota. Priority 1; Participating agencies - DOA, DOI, EPA, TVA; Contributing - NSF; Five years beginning in 1980.

3. Determining the Relative Contribution of Nitric and Sulfuric Acid Inputs

Both nitrogen and sulfur are important plant nutrients. Only nitrogen, however, is limiting to productivity in some aquatic systems. Studies will be undertaken to determine the relative contribution of nitrogen and sulfur from acid deposition to the productivity and/or acidification of aquatic ecosystems. Important questions will be examined as to the amount and seasonality of nitrogen reaching streams and lakes from forested watersheds receiving precipitation in which nitric acid makes up a major part of the acidity. Priority 1; Participating agencies - DOA, DOI, EPA, TVA; Contributing - NSF; Five years beginning in 1981.

4. Evaluating the Significance of Mobilization of Toxic Metals

Analyses will be made of the extent to which metal contamination in drinking water, food crops, and fish is due to acid deposition and subsequent leaching and mobilization of metals. Influences of acid deposition will

be isolated from those of acid mine drainage, fertilization, irrigation with contaminated water, and the like. Priority 2; Participating agencies - DOA, DOI, EPA, TVA; Contributing - DOE; Five years beginning in 1982.

5. Modeling Watershed Dose/Response Relationship

Using the best data bases from Tasks E-1, 2, and 3 above, attempts will be made to develop simple empirical models relating the readily measured chemical characteristics of lakes and streams to atmospheric deposition. The model developed by Henriksen is one that will be tested to determine its applicability to North American lakes, but models relating stream responses (especially during runoff events) also must be developed and tested. Special attention will be given to factors such as dissolved organic matter, nutrient cations, and metal-ion concentrations, which may affect these models.

At the same time, relatively detailed simulation models of the acidification process and its effects will be developed and evaluated. One major contribution is being developed at research sites in New York (the ILWAS model), but development and validation at other locations are needed to improve confidence in the predictive tools available. Such studies require calibrated watersheds from study sites in sensitive areas where both terrestrial (soils and vegetation) and water quality research can be carried out jointly. Locations that already have some data and that should be considered in the development of additional model validation data include: 1) ILWAS Project - New York (EPRI), 2) Hubbard Brook - New Hampshire (FS and NSF), 3) Corbin Creek - Georgia (TVA, FS, FWS, USGS, EPA), 4) Raven Fork Creek - North Carolina (TVA, FWS, NPS), 5) Coweeta - North Carolina (FS and NSF), 6) Northern Highlands LTER site - Wisconsin (NSF), 7) Filson Creek (BWCA) - Minnesota (USGS and EPA), 8) Camp Branch - Tennessee (TVA and EPA), and 9) Walker Branch - Tennessee (DOE).

The goal of this research will be to have the most complete, quantitative long-term dose/response models evaluated fully and compared with the more empirical field relationships now in use. In support of this validation process, every effort will be made to maximize the use of existing information from all sources. Priority 1; Participating agencies - DOI, DOA, EPA, TVA; Contributing - DOE, NSF; Five years beginning in 1981.

6. Studying Acidification of Drinking-Water Sources

Some historical records are available on long-term changes in the acidity of municipal reservoirs, such as the Hinkley reservoir of Utica, New York. The recent discovery of acidified groundwater in western Sweden suggests that there may be similar regions in the U.S. Analyses will be made of historical records and current data from public drinking water systems, whether using groundwater or surface water reservoirs, to determine whether pH or potentially significant metal concentrations have changed during the past 10 to 30 years. Where acidification is found, the chemistry of water supply lines will be studied and estimates will be made of the possible impact on human and livestock populations. Groundwater records will also be studied to estimate the acidification of individual supplies. Priority 1; Participating agencies - EPA, DOI; Contributing - HHS; Four years beginning in 1980.

7. Monitoring Drinking Water and Evaluating Treatment Methods

Ongoing programs within EPA to monitor pH and heavy-metal concentrations in public drinking water systems, reservoirs, and groundwater sources will be expanded. Investigations also will be made of how much effect chemical treatments, such as lime or other alkaline solutions, have on the acidity of surface water or groundwater sources of drinking water. The possible short and long-term usefulness of this ameliorative approach on human health will also be determined. Priority 2; Participating agencies - EPA, [illegible] - HHS; Three years beginning in 1983.

Biological Productivity of Aquatic Systems

Research results are beginning to yield improved understanding of the effects of acid deposition upon fish and fish recruitment, but much more precise dose response information is needed on long-term studies that will demonstrate reliable, repeatable research findings. The following studies are proposed to provide that understanding.

8. Monitoring Regional Trends in Biological Effects

Past and current records of fish populations and major habitat qualities will be evaluated at locations where well-documented data are available. The number of lakes affected by acid precipitation will be determined and the extent of the biological changes in them evaluated. Scientists will seek to identify lakes and streams believed to have been affected by or apparently tolerant to acid deposition. Information on fish-eating birds of prey and fur-bearing mammals also will be sought. This information will be useful for (1) identifying possible source-regions in which emissions of SO_2 and NO_x may need to be reduced, (2) identifying lakes, streams and groundwaters for study of mitigation methods, (3) determining the chemical or biological basis of acid tolerance and susceptibility, and (4) determining the chemical or biological basis of acid tolerance and susceptibility. Priority 1; Participating agencies - EPA, DOI; Contributing - TVA; Four years beginning in 1980.

9. Studying Watershed Productivity

Some of the calibrated watershed investigations cited above will be used to examine changes in species composition, population dynamics, reproductive behavior, and productivity of selected fish species and their supporting food chains. Biological effects modeling by the FWS has documented many aspects of the needed research approach. If possible, these studies will take place at selected sites representing a range in lake and stream types, such as high mountain lakes in recently glaciated areas, brown-water lakes in interior and coastal-plains locations, and soft-waters [illegible] sandy soils.

Measurements will be made of progressive changes in: (1) the chemistry of the open-water system and sediments; (2) the types and numbers of surface, subsurface, and bottom-dwelling insects, plants, animals, and micro-organisms; and (3) potential productivity, (using predictive models when necessary). Efforts will be made to establish correlations between the chemical properties of the water or lake sediments and the populations and reproductive success of the various organisms. Analyses of these relationships should improve the understanding of the biological effects of acidi-

fication and the linkages between water quality and changes in the forms of life and productivity in lakes and streams. Priority 1; Participating agencies - EPA, DOA, DOI, TVA; Contributing - DOE, NSF; Ten years beginning in 1980.

10. Identifying Vulnerable Growth Stages

Field and laboratory experiments will be conducted with aquatic animals, plants, and micro-organisms to identify times of reproduction and stages of growth that coincide with episodes of strong acid inputs such as (1) snow melting in spring, (2) the presence of stagnant air masses followed by either very heavy or very light rains in summer or very wet snows in winter, and (3) moderate rains following prolonged drought in summer or early fall. This information may be useful for developing emissions-management strategies to avoid coincidence between major episodes of acid deposition and the reproductive and sensitive-growth stages of very valuable organisms. Priority 1; Participating agencies - DOI, EPA; Contributing - DOE, NSF; Five years beginning in 1980.

11. Studying Metal Contamination of Fish

Analyses will be made of historical records, fish samples, and trophy fish to determine if concentrations of toxic metals in fish have changed over time. These data will give partial evidence of long-term trends possibly significant to human health. Priority 2; Participating agency - DOI; Contributing - EPA, DOE; Two years beginning in 1981.

12. Analyzing Mitigation Strategies for Acidified Lakes

Various management procedures by which lakes can be protected from the harmful effects of acid deposition and associated metal-ion toxicity will be tested first by small-scale, and later by large-scale field experiments. These tests will be done both where fish populations have been reduced by acid deposition and where fish populations are still nearly normal. These investigations will be supplemented by the findings of current Scandinavian studies.

Experiments will include the application of various types of acid-neutralizing materials, such as powdered lime, rock limestone, and organic or inorganic materials that would bind or inactivate toxic metal ions. These materials will be applied in various ways to the surrounding drainage basin at the shorelines, and in deep waters of the treated lakes and streams (with and without restocking with young fish). Economic analysis will be done to assess cost-benefits. These experiments will be useful in developing management procedures for especially valuable lakes and streams. Priority 2; Participating agencies - DOI, DOA, EPA, TVA; Five years beginning in 1982.

F. Research on Terrestrial Impacts
(Coordinating Agency-DOA)

As indicated in the Information Needs Section, terrestrial impacts relate not only to the direct influences of acid precipitation and its interaction with other air pollutants, but also to the fluxes of nutrients, acid, and other ions into the waters draining these systems. Thus, each of the following

sections deals with both direct acid deposition/plant effects, as well as indirect soil and watershed effects. The latter will be coordinated with research programs on Aquatic Impacts.

Forest Trees and Range Plants

Because we lack definitive information on the extent to which acid rain affects forest trees and range vegetation, the following research projects will be undertaken to obtain such information:

1. <u>Studying Effects on Growth and Productivity of Forest Trees and Range Plants</u>

   A series of comparative field experiments will be initiated to determine the beneficial or injurious effects of wet and dry deposition on the growth of selected forest trees and range plants. These studies will include a variety of approaches: (1) analyses of tree-rings in increment cores from paired sets of plantings on adjacent sites subject to acid precipitation; (2) dose-response studies using simulated rains of various pHs on rangeland, forest seedlings, and young saplings; (3) dose-response studies using simulated rains of various pHs on a wide range of tree species and range plants growing on different types of soils; (4) multiple-pollutant exposure tests to determine if mixtures of acid rain, road salts (chlorides), and gaseous pollutants such as ozone, SO_2, and NO_x interact cumulatively or synergistically; and (5) analyses of throughfall and stemflow composition as they effect growth and productivity. Since these studies involve possible effects of toxic metals in soil solution, some of them may need to be developed in conjunction with watershed and water quality effects research. These studies will provide valuable information for use in long-term effects projections for forest and range management. <u>Priority 1; Participating agencies - DOA, EPA, DOI, TVA; Contributing - DOE, NSF; Ten Years beginning in 1980</u>.

2. <u>Identifying Vulnerable Growth Stages in Plants</u>

   A series of greenhouse and field tests will be made to identify life forms, life stages, and life processes in forest trees and range plants that are vulnerable to natural and simulated acid rain. These experiments will test the effects of acid rain on the fertilization of flowers, the germination of seeds, and the establishment of young seedlings. Effects of acid rain on plant responses to biotic and abiotic stresses will also be investigated. This information will be useful in understanding the vulnerability of various growth stages of forest and range plants to acid deposition. Studies will be augmented by long-term field tests. <u>Priority 1; Participating agency - DOA; Contributing - DOE, EPA; Ten years beginning in 1980</u>.

3. <u>Investigating Effects on Metabolic Functions and Cellular Structures</u>

   Various species of forest trees and range plants will be exposed to simulated and naturally-occurring dry and wet deposition to evaluate their responses. Determinations will be made of their susceptibility to erosion of protective waxes. Where significant biological changes are detected, further tests will be made to determine if such responses condition the trees and plants to damage by abiotic stresses. Similarly controlled lab-

[illegible] and field tests will be made to determine if acid rain affects the quality and amount of wood fiber produced by various species of trees, their root growth and function, and their ultrastructural and cellular activities. These data will provide information on the physiological and biochemical processes by which plants may be changed by acid deposition and metal-ion toxicity. Priority I; Participating agency - DOA; Contributing - DOE, NSF; [illegible] years beginning in [illegible].

6. Analyzing Acid Deposition-Induced Predisposition of Forest and Range Plants to Diseases and Insects

Experiments will be initiated to determine if acid precipitation predisposes forest trees and range plants to injury by various diseases and insects. The pathogens to be tested will include fungi, bacteria, nematodes, viruses, parasitic seed plants, and insects that attack the foliage, stems and roots of trees and range plants. Experiments will be conducted in greenhouses, growth chambers, field plots, and at experimental forest and range sites. Results of this research will be useful for estimating ecosystem impacts and for developing management options. Priority I; Participating agency - DOA; Contributing - EPA; Five years beginning in [illegible].

Agricultural Crops

[illegible] research in controlled environments and in the field will be undertaken to determine the effects of acid rain on the growth, productivity, and [illegible] of major [illegible], feed, forage, and fiber crops. These studies will [illegible] assessments of the consequences of acid precipitation and development of possible mitigation methods.

1. [illegible] of Crop Species Sensitivity

A variety of major agricultural crops will be exposed to simulated acid rain and natural atmospheric deposition of known chemistry. Common varieties of each crop species will be tested in different geographical locations. Tests with an array of growth stages of each plant will provide information on vulnerability at each growth stage. Measurements will be made of direct and indirect effects on crops and their susceptibilities to other stresses. When a crop species is discovered to be sensitive, an array of varieties within that species will be tested for genetically controlled resistance and susceptibility to harmful effects of atmospheric deposition. Priority I; Participating agencies - DOA, DOI, TVA, EPA; Contributing - DOE, NSF; Five years beginning in [illegible].

2. Developing Dose-Response Relationships for Crop Growth and Yield

Dose-response relationships between various substances in acid precipitation and dry deposition and crop injury will be determined both singly and in specific combinations for gaseous pollutants. Particular attention will be given to determining the specific amounts of acids that can injure foliage, inhibit seed germination, affect metabolic functions or otherwise damage cultivated crops. Investigations will be made of the effects of acid deposition on disease virulence, persistence, spread, genetic shifts, host parasite interactions, symbioses, mechanisms of plant-disease resistance or susceptibility, infectious processes, and economic consequences. This information will be useful in identifying threshold doses above which

plant productivity will be adversely affected and for estimating economic losses. Priority 2; Participating agencies - DOA, EPA; Contributing - DOE, TVA; Five years beginning in 1982.

7. Investigating Acid-Deposition Induced Predispositions of Crops to Susceptibility to Diseases and Insects

Whole agroecosystem approaches and laboratory and greenhouse experiments will be conducted to learn if acid rain predisposes crops to harm by diseases, insects, and environmental stress factors such as drought and salinity. Determinations will be made of natural atmospheric deposition and simulated acid rain on the abundance and species diversity of plant pathogenic fungi, bacteria, viruses, and abundance of nematodes, weeds, insects, and insect parasites and predators. Interaction with related air pollutants such as oxidants and SO_2 will also be defined. These epidemiological experiments will involve major agricultural crops. Economic data on crop losses also will be obtained. These data will be useful in identifying interrelationships between agriculture crops and abiotic and biotic stresses to aid in developing reliable cultural procedures. Priority 3; Participating agencies - DOA, EPA; Five years beginning in 1982.

8. Analyzing Metal Contamination of Crops

Due to the fact that several metals can become relatively mobile in sensitive soils during periods of high acid inputs, tests should be made of the potential for metal ion uptake by crops via their foliage and root systems. Analyses will be made of herbarium specimens, historical records, and early plant nutrition studies to determine if concentration of heavy metals in food crops have increased over time. Evidence of long-term trends in possible metal accumulation may result from these studies. Studies also will be initiated to determine what foliar symptoms may be used to indicate metal toxicities if they were to occur on certain acid soils (e.g., oats in areas of the northeast). Priority 3; Participating agency - DOA; Contributing - DOE, HHS; Two years beginning in 1982.

Soils

Atmospheric deposition of acids may have significant and long-term effects on terrestrial ecosystems through the alteration of soil processes and soil chemistry. These impacts may then affect surface and groundwater and aquatic ecosystems. Research will be directed to developing criteria for identification of acid-vulnerable soils and watersheds, their areal distribution, and their chemistry and biology.

9. Characterizing Soil Vulnerability

Existing knowledge of soil characteristics and climatic factors will be analyzed and evaluated to establish the usefulness of various soil properties for predicting the vulnerability of soils or soil solution to acid deposition. Factors affecting high sulfate retention allow direct acidification of soil water. Current survey and historical data from state and federal agencies will be integrated into the evaluation and development of soil-vulnerability criteria. Mapping procedures for considering the soils within a small watershed as one unit and for aggregations into larger watersheds will be examined and documented. Area, regional, and state

maps of soil, watershed, and water quality vulnerability will be developed in a form suitable for complementing the modeling and trend projection methodologies described under Aquatic Impacts. Priority 1; Participating agencies - DOA, DOI, EPA; Three years beginning in 1982.

10. Studying Effects on the Ability of Soils to Support Vegetation

Information is needed on the relationship of acid deposition to changes in the ion exchange capacity and base saturation of soils, critical levels of essential and toxic metals relative to variations in soil properties and types of vegetation, inputs of essential elements, and changes in the capacity of soils to support regeneration and growth of forest trees and range vegetation. Research topics will include effects of acid deposition on: (1) the transformation of phosphorous, nitrogen, and sulfur; (2) the mobilization of aluminum and its toxicity to crop and tree roots; (3) the physical, chemical, and biological processes that lead to availability of nutrients to plants; (4) soil capacities for absorbing toxic metal ions; and (5) changes in soil fauna and flora. This research information will be useful for determining the effects of soil chemistry on biological productivity. Priority 1; Participating agencies - DOA, EPA, DOE; Contributing - NSF, TVA, Five years beginning in 1980.

11. Analyzing Soil Degradation Mechanisms and Mitigation Measures

Soils known to be sensitive to acid deposition will be subjected to accelerated acid treatments in the laboratory and the field to obtain information on the nature of the degradative mechanisms. Various treatments and amendments will be added to the soils at several stages of the degradation process to determine possibilities for mitigation or if the degradation process is irreversible. These studies will be useful for developing management options and mitigative measures for degraded soils. Priority 1; Participating agencies - DOA, EPA; Five years beginning in 1982.

12. Analyzing the Buffering Capacity and Response of Watersheds to Acid Deposition

In conjunction with the calibrated watershed studies, research will be undertaken to evaluate the combined influences governing the capacity of soils and watersheds to resist changes in pH, nutrients released to drainage water, sulfur retained or lost, and in the tendency of some soils to hold or release aluminum and other potentially toxic metals. The stability of chemical exchange complexes in the soil in the presence of changing soil chemistry also is an important question. Changes in soil structure and mineral composition will be determined, and kinetic models will be developed to describe both normal equilibrium relationships and the responses to added acid, sulfate, or nitrate. Microbiological studies will focus on the nitrogen and sulfur transformations in soils influenced by acid precipitation. Research on decomposition processes in forest litter and other organic matter already underway at NSF sponsored sites will be utilized to determine the sensitivity of these processes to acid precipitation.

The results from this process oriented research will be compared with results from other countries and with the empirical water quality models (see previous section) so as to advance the overall understanding of

[illegible] The soil studies will clarify processes of weathering [illegible] and organic decomposition and their subsequent influences [illegible] among soil, water, and plant components. Priority 1; [illegible] - USDA, EPA, TVA; Contributing - DOI, DOE, NSF; Five [illegible]

[illegible] Materials and Cultural Resources
([illegible] Agency-DOI)

[illegible] recognized pertaining to the effects caused by [illegible] materials, structures, and cultural resources. The [illegible] field observations and surveys of damage to various [illegible] to determine how acid deposition affects [illegible] support for this research will also be sought from [illegible] affected by the effects of acid precipitation [illegible] studies are identified for research:

[illegible] Materials and Cultural Resources

[illegible] Determine the effects of acid precipitation on [illegible], natural waters, and soils and to correlate these [illegible] monitoring studies (atmosphere, water, soil) to [illegible]. Initially this task will be based primarily [illegible] may also include exposure of materials in conjunc[illegible] Network and the National Trends Network. In [illegible] nonmetallic structural, construction, and other [illegible] will be exposed both to simulated and to naturally- [illegible] related rural and urban areas. Objectives [illegible] (1) the mechanisms of metallic corrosion and [illegible] in the atmosphere; (2) possible differences [illegible] effects of acid rain and the effects of SO_2 and NO_x [illegible] acid on the surface of materials; (3) critical [illegible] degradation--especially for destruction of [illegible] and (4) the mechanism of degradation of mate[illegible] by acid precipitation. This research should [illegible] and standard test methods and thus should [illegible] materials and the quantitative measurement [illegible] and a scale for ranking materials accord[illegible] acid precipitation. Priority 1; Participating [illegible] - DOC (NBS), GSA, DOD; Five years begin[illegible]

[illegible] of Cultural Resources

[illegible] Determine what cultural, memorial, and historical [illegible] are being subjected to damage by acid precipita[illegible] western sites will also be examined. [illegible] using the construction materials sensitivity [illegible] developed earlier in this research along with dose-response [illegible] other investigations. This survey will provide estimates [illegible] at these sites and will prescribe the urgency for [illegible] from further destruction. Priority 1; Participating [illegible] EPA; Contributing - GSA, DOC (NBS); Five years begin[illegible]

3. Estimating the Costs of Materials Damage

With the methods and data developed in Task G-1, both national and regional estimates of damage to parent and replacement materials including service life predictions, maintenance costs, and related expenditures from acid deposition will be prepared based on methodologies developed by the National Bureau of Standards. Estimates will first be made for the northeastern quadrant, extended to include the entire eastern half of the country, and then to areas in the west. Determination of acid deposition costs to affected areas of the U.S. will include determinations of the urgency for developing mitigative measures and for making changes in present and intermediate term policy. Priority 2; Participating agency - EPA; Contributing - DOC (NBS), DOI, GSA, DOE; Three years beginning in 1984.

4. Research on Protective Coatings and Mitigative Treatments

Presumably private industry will continue its major role in developing coatings and treatments to protect metals, paints, plastics, fabrics, and stone and concrete structures from the effects of acid precipitation. The Federal Government, which has a major responsibility for the preservation and maintenance of historic monuments, memorials, and statues, will establish laboratory and field programs for developing mitigative preservation techniques. Initial research is now underway in cooperation with European nations whose historical artifacts have been affected more severely than those in this country. (Note: The NATO Committee on Challenges to Modern Society has an active program in this area.) Priority 3; Participating agencies - DOI, EPA; Contributing - GSA, DOC (NBS), DOD; Three years beginning in 1983.

H. Research on Control Technologies
(Coordinating agency - EPA)

To estimate the costs and benefits, both direct and indirect, associated with alternative concepts to control acid rain, a knowledge of the limitations and effectiveness of specific control technologies is required. Control technologies for acid precipitation limit emissions of the precursors SO_2 and NO_x criteria pollutants under the Clean Air Act. Technologies for control are already in place or under evaluation to meet requirements under State Implementation Plans for existing sources, New Source Performance Standards (NSPS) for newly constructed sources, and emission standards for motor vehicles or engines. Examples of technologies in place or under evaluation by EPA, DOE, TVA, or industry to meet current environmental standards include wet scrubbers, low-NO_x burners, three-way automobile catalytic converters and combustion modification, and fluidized bed combustion. In addition, physical coal cleaning is an established technology for removing pyritic (inorganic) sulfur from coal before shipment. Policy analysis activities under this Plan will monitor the use and potential of these technologies.

Most control technologies for airborne acids and their precursors are not uniquely applicable to the amelioration of acid precipitation. For instance, acid precipitation is only one possible issue involved in considering the control of man-made emissions of SO_2 and NO_x. The National Acid Precipitation Assessment Program does not specifically include funding for control technology research because the portion of that work solely germane to acid rain cannot generally be determined. The Task Force does, however, identify,

evaluate, and coordinate the federal control technology research and development (R&D) activities that are relevant to acid precipitation.

Particular emphasis will be given to evaluating cost effective technologies retrofittable on older combustion sources not required to meet NSPS. Since commercialization of technologies is not an appropriate role for government, emphasis will be placed on technology evaluation and communication of information to the private sector.

A number of areas that generate significant amounts of acid rain precursors have been identified in this report. These areas include thermal power generation, smelters, mobile sources, and industrial/commercial boilers. A number of related applied R&D activities appear to be worthwhile efforts needed to provide additional tools in future acid rain precursor reduction efforts, and are described below under each of the areas involved.

1. Thermal Power Generation

R&D efforts that will be considered for acid precipitation mitigation in this area include:

a) Projects Affecting SO_2 Emission Reduction

o A near-term project to demonstrate emission reductions achievable with, and the economics of, spray dryer flue gas desulfurization (FGD) processes applied to high sulfur coals. If successfully demonstrated, this process could be appreciably less costly than lime/ limestone FGD from both capital and operating cost standpoints for low to medium sulfur removal efficiency levels (50 to 75%). A commercial-scale spray dryer FGD facility already in operation and capable of handling high-sulfur coal, could be used for testing purposes by an appropriate organization.

o R&D is needed on advanced particulate control concepts that will lower the capital cost and operating costs associated with spray dryer SO_2 control. In this regard, an ongoing EPA pilot-scale project on Electrostatically-Enhanced Fabric Filtration (EEFF) offers excellent potential for materially reducing the size (and cost) of the fabric filter associated with the spray dryer FGD process.

o Demonstration-scale project results are needed to verify promising U.S. bench and pilot plant scale testing as well as commercial-scale German application of the Limestone Injection/Multistage Burner (LIMB) technology for SO_2 and NO_x reduction. Results of EPA-sponsored pilot plant efforts in the U.S. indicate that 50 to 70 percent of sulfur can be removed from a range of low to high sulfur coals using calcium to sulfur stoichiometries of 2-3.

o Adipic acid enhancement of limestone FGD has been demonstrated by EPA at the pilot plant and commercial-scale levels as a technically and economically feasible means of improving SO_2 removal efficiency as well as improving limestone utilization and process reliability. However, more commercial-scale testing is needed on a variety of coals and operating conditions, to completely establish this process as a

worthwhile tool for SO_2 reduction. Adipic acid enhancement of limestone FGD could permit the burning of high-sulfur coals, i.e., 4-6 percent sulfur, and still achieve substantial SO_2 removal efficiencies (70-90 percent) in retrofit situations for acid rain control purposes, at a reasonable cost.

b) Projects Affecting NO_x Emission Reduction

o Long-term demonstration projects on improved control technology for NO_x reduction, i.e., advanced low NO_x burners on pulverized coal-boilers, should be initiated on commercial-size units.

2. Non-Ferrous Metal Smelters

R&D efforts that will be considered for acid precipitation mitigation in this area include:

o Process/control technology development for the reduction of SO_2 emissions from non-ferrous metal smelter weak SO_x waste gas streams. Alternative acid plant configurations need to be studied.

o Innovative technologies that would reduce or eliminate SO_2 emissions from smelting operations need to be tested and demonstrated.

3. Industrial Boilers

R&D efforts that will be considered for acid precipitation mitigation in this area include:

o A long-term demonstration project on SO_2 reduction using coal-limestone pellets as feed to large stoker-fired boilers.

o A commercial-scale industrial boiler employing a retrofitted spray dryer FGD process could be used to establish economically and technically feasible SO_2 control on industrial boilers burning high-sulfur coal using this process.

4. Additional Mitigation Areas

o Development of systems/technology to accelerate the reduction of NO_x emissions from existing transportation fields.

o Continuation of long-term development efforts to develop alternative cleaner, less expensive methods of coal combustion such as fluidized bed combustion, solvent-refined coal, coal-oil mixtures, and coal gasification.

I. Assessment and Policy Analysis (Coordinating Agency-EPA)

Considerable information on the amount, composition, and location of acidic deposition is already available. The current and potential damage attributable to acid deposition is uncertain. Another poorly understood aspect of the acid rain phenomenon is the process in which sulfur oxides, nitrogen oxides, and other substances interact to form the acids and acidifying materials deposited in both wet and dry forms of acid deposition.

Existing and new findings from other research activities will be brought to bear on the problem of effective emission control and effects mitigation strategies. These activities will also reveal the critical needs for more or better data, models, and research activities in order to proceed with the policy analysis process.

The following tasks will be pursued in this area:

1. <u>Compilation and Evaluation of Costs and Performance of Potential Mitigation Measures</u>

   Information about costs and performance of a wide range of options for both control of emissions related to acid precipitation and mitigation of effects at the receptor will be updated as it becomes available from the control technology, aquatic effects, and other Task Groups. Site-specific information on engineering costs and performance of these options will be evaluated and generalized to categories of sources or receptor areas in specified regions. This information will then be available for the comprehensive comparison of costs and economic benefits of alternative strategies in the integrated assessment process. Guidance will be provided to the control technology and effects task areas concerning assumptions and procedures for estimating costs and performance of emissions control and mitigation measures. <u>Priority 1; Participating agency - EPA; Contributing - DOE, DOI, DOA; Nine years beginning in 1982.</u>

2. <u>Integrated Assessment of the Acid Precipitation Phenomenon and Potential Mitigation Measures</u>

   The fundamental purpose of carrying out all acid precipitation research is to provide a basis for resolution of policy questions. Integrated assessment is the mechanism whereby scientific research activities and results are brought to bear upon policy issues. The integrated assessment process links together the best available information from all technical research areas to assess the current and projected status of the acid precipitation problem and to analyze alternative emission control and effects mitigation strategies. It is anticipated that this process will ultimately organize research results into a framework which allows comprehensive cost/benefit analysis of such alternative strategies. Early iterations of the integrated assessment process will focus heavily on intermediate objectives which are useful in management of the overall research process. These interim objectives will be identified by the:

   (a) Systematic analysis of the major types of uncertainties in current knowledge and assessment of the sensitivity of policy-oriented conclusions to various types of uncertainty;

   (b) Identification of technical problems in the ongoing research program, such as gaps and overlaps in effort and inconsistencies in assumptions, units, or levels of details, which must be resolved in order to address policy questions;

   (c) Short-term analyses of key issues such as appropriate sizes of source and receptor regions for policy analysis, and appropriate assumed retirement age for major energy facilities;

(d) Development of specifications for data bases and methodologies to be prepared in other task areas and used in assessments.

Priority 1; Participating agencies - EPA, DOE; Contributing - DOA, CEQ, DOI; Eight years beginning in 1982.

3. Preparing Special Scientific and Policy Assessment Documents

In addition to the regular assessments presented in the Program's Annual Reports, special in-depth assessments will be done periodically for specific purposes. Examples are assessments of aquatic effects, atmospheric processes, and man-made emissions. A list of the special assessments through 1986 and their completion date is given in Part V, Section C.

Primary responsibility for generating the technical information for each assessment rests with the agency which coordinates work in the appropriate research category. The Assessments and Policy Analysis Task Group will oversee and contribute to the special assessments to ensure that they address the relevant policy questions and are structured in such a way as to be useful to policymakers. Priority 1; Participating agencies - DOA, DOE, DOI, EPA, NOAA; Contributing - DOS, HHS, NASA, NSF, TVA; Nine years beginning in 1981.

4. Program Information and Coordination Activities

A variety of information collection and dissemination activities and coordination functions are essential to the smooth operation of the research program. These will be funded within the Assessment and Policy Analysis component of the program and will be coordinated through the Task Force's Program Coordination Office with input from the Research Coordination Council. These activities include assembly of the Annual Report, research project inventories, and program review workshops. Priority 1; Participating agencies - DOA, EPA, NOAA, DOE, DOI, CEQ, NSF; Ongoing throughout the Program.

V. PROGRAM MANAGEMENT AND COORDINATION

A. General Strategy

The Acid Precipitation Act of 1980 (Title VII, PL 96-294) mandates a comprehensive national program of policy-oriented research to assess the phenomenon and consequences of acid precipitation. The National Acid Precipitation Assessment Program (NAPAP) is directed toward providing input for decision making in the areas of energy production, natural resource management, and environmental policy. The Program not only links the efforts of the federal agencies, but also coordinates them with the research and monitoring of activities of the private sector, state and local governments, and fosters cooperation with the international research community.

The National Acid Precipitation Assessment Program will use the following strategy:

o <u>Build Upon Previous Efforts</u>--The Program, in accordance with its enabling legislation, will use the results of the previous efforts to develop a federal acid rain program. The former Acid Rain Coordinating Committee (ARCC) has been reconstituted into the statutory Task Force and the ARCC draft plan was used as the foundation for developing this Plan.

o <u>Use Existing Knowledge</u>--The Program builds upon the base of knowledge and experience already accumulated by U.S., Canadian, Scandinavian, European, and other scientists. Coordination will be maintained and strengthened between federally funded research and research supported elsewhere. Available research results will be used to provide guidance in the design of future research and monitoring efforts.

o <u>Establish a Long-Term National Trends Network</u>--The development and long-term maintenance of a carefully designed National Trends Network (NTN) is essential in order to provide a continuous record of data for use in documenting and understanding changes in the chemistry of acid deposition. The highest possible standards of quality control and assurance will be used in the operations of the NTN. Existing monitoring networks, such as those of the National Atmospheric Deposition Program (NADP), will be integrated into the NTN to the maximum extent feasible.

o <u>Conduct Research to Develop New Knowledge</u>--The program described in this Plan is intended to increase our understanding of the phenomenon and consequences of acid precipitation. The emphasis in the proposed research is on activities that most effectively contribute to establishing a firmer basis for decision making. The Program will utilize the expertise available in federal and state agencies, universities, industry, private contractors, and research institutions. Information from research activities initiated as part of the National Program will become available in 1982, and will continue to be produced throughout the remainder of the decade.

o <u>Evaluate Information Continually</u>--Information generated by the National Acid Precipitation Assessment Program (NAPAP), and other research in this country and abroad, is expected to add rapidly to our knowledge. The information produced will be periodically synthesized, subjected to scientific peer review, and interpreted to guide decisions on future research and policy. The Task Force will report annually to the President

and Congress on the Program's progress and implications of the existing knowledge.

B. Organization And Responsibilities

1. The Task Force

The Interagency Task Force on Acid Precipitation is jointly chaired by three federal agencies: the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA). The other participating federal entities are: the Departments of Interior (DOI), Health and Human Services (DHHS), Commerce (DOC), Energy (DOE), and State (DOS); the National Aeronautic and Space Administration (NASA); the Council on Environmental Quality (CEQ); the National Science Foundation (NSF); and the Tennessee Valley Authority (TVA). Each agency is represented on the Task Force by a policy-level member.

The Task Force membership also includes the Directors of Argonne, Brookhaven, Oak Ridge, and Pacific Northwest National Laboratories and four Presidential appointees. An organization chart for the Task Force is shown in Figure 7.

The primary responsibilities of the Task Force are to:

- o Develop and update the National Acid Precipitation Assessment Plan;
- o Oversee and implement a comprehensive ten-year research program that coordinates and focuses the activities of the federal agencies;
- o Provide Annual Reports on the research program's progress and their implications;
- o Maintain an inventory of federally funded acid precipitation research projects;
- o Produce an annual interagency budget for the federal program;
- o Assist productive interaction between federal efforts and private sector, academic, state and local government;
- o Obtain nonfederal input to the planning and program activities; and
- o Disseminate program results and assessments of their implications.

The Task Force works with all those concerned to ensure that the programs of the individual federal agencies are conducted as part of a comprehensive, well-coordinated, and long-term National Program. All the acid precipitation research and assessment activities of the federal agencies are carried out in the context of the National Program defined by the ten-year Plan and with oversight by the Task Force. Memoranda of Understanding and other kinds of cooperative agreements between the agencies are used to formalize or to clarify relationships and responsibilities.

INTERAGENCY TASK FORCE ON ACID PRECIPITATION

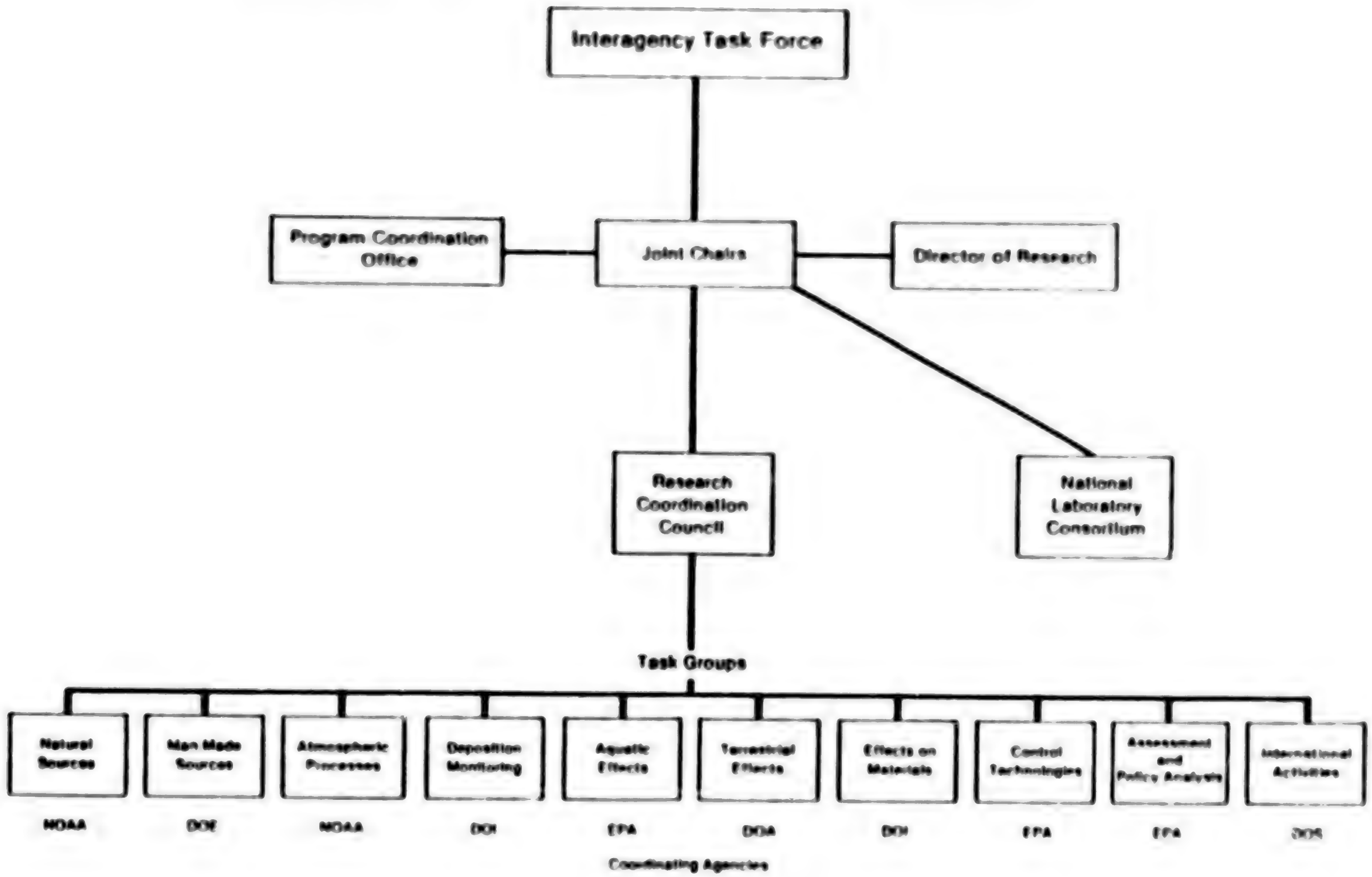

Figure 7. Organization chart.

The Task Force has no regulatory authority but is responsible for conducting a research program to provide a firmer scientific basis for formulating action to address acid rain. Annual Reports and special assessment documents will be issued periodically by the Task Force, evaluating the current state of our knowledge, outlining what further research is needed, and describing the implications of available information.

2. Program Coordination Office

The Program Coordination Office of the Task Force serves an interagency function and provides a focal point for coordinating and staffing the activities of the Task Force. The Office is managed by the Task Force's Executive Director, who is appointed by the Joint Chairs. In carrying out its responsibilities, the Office works closely with, and reports to, the Task Force Joint Chairs and is assisted by individuals designated by each of the participating federal agencies.

The Program Coordination Office's functions include:

- o Staffing the preparation of the annual interagency budget;
- o Coordinating the preparation of the Annual Report to the President and the Congress;
- o Serving as liaison and coordinator for activities requiring interagency representation;
- o Responding to inquiries for information about the National Program and Task Force;
- o Organizing workshops and other meetings; and,
- o Arranging for and staffing Task Force and Research Coordination Council meetings.

The Program Coordination Office facilitates interagency communication and makes provisions for disseminating information on the Program and Task Force activities. This includes keeping the Joint Chairs, Research Coordination Council, and full Task Force generally informed about the Program, as well as directing inquiries on specific aspects of the Program to the appropriate sources. The Office performs an information clearinghouse function to ensure dissemination of documents, such as the National Plan, Annual Reports and workshop results. The Program Coordination Office also serves as the primary contact point for states, private groups, and the public.

3. Technical Task Groups

The Task Force has ten working-level Task Groups, one for each of the National Program's nine research categories and one for international activities. These technical groups include program managers and experts from all the participating federal agencies. They are responsible for detailed planning and implementation of the efforts in their assigned areas. A Coordinating Agency has been identified for each Task Group to provide a point of contact and coordination. The ten Task Groups and their Coordinating Agencies are listed below:

Task Group		Coordinating Agency
A.	Natural Sources	NOAA
B.	Man-made Sources	DOE
C.	Atmospheric Processes	NOAA
D.	Deposition Monitoring of Acidic Substances	DOI
E.	Aquatic Impacts	EPA
F.	Terrestrial Impacts	DOA
G.	Effects on Materials and Cultural Resources	DOI
H.	Control Technologies	EPA
I.	Assessment and Policy Analysis	EPA
J.	International Activities	DOS

Designation as Coordinating Agency involves responsibility in the assigned category for:

- o Coordinating and facilitating program implementation;
- o Providing the Task Force with assessments of progress in attaining goals described in the National Plan;
- o Coordinating the flow of budget and program information;
- o Supplying input and assistance to the Research Coordination Council in drafting Plan revisions, Annual Reports, and the interagency budget;
- o Facilitating coordination with nonfederal groups and activities and assuring the solicitation of input from such groups; and
- o Encouraging and maintaining interagency cooperation in the assigned area.

Each Task Group has a leader who is a member of the Research Coordination Council. Task Group leaders are charged with keeping their members informed of and involved in Task Force activities.

4. Research Coordination Council

The Research Coordination Council is responsible for integrating the efforts of the various Task Groups and develops draft reports, program plans, budgets, and other recommendations for consideration by the full Task Force. The Joint Chairs designate the chairperson of the Council to oversee its efforts. The Council includes the leaders of all the Task Groups, the chairperson of the National Laboratory Consortium, and other appropriate agency representatives. The Council meets at least four times a year to oversee the Task Groups and to provide input to the full Task Force.

The Council is responsible for:

- o Carrying out policies and programmatic decisions determined by the full Task Force;

- Updating research results and their implications for the Task Force;

- Bringing management problems and proposed research plan revisions to the attention of the Task Force;

- Responding to the recommendations of advisory groups, workshops, and the Director of Research regarding potential gaps or undesirable duplications in the research agenda;

- Preparing and maintaining a detailed operating research plan for the National Program;

- Providing for peer review of program outputs, such as the first critical assessment document;

- Recommending program changes or budget levels to the Task Force; and

- Providing a forum for discussing and examining research results.

Nonfederal researchers and managers may periodically be invited as observers or participants in the Council's deliberations. It is the Council's responsibility to ensure integration of appropriate nonfederal research results into the body of knowledge for use by decision makers to deal with the phenomenon of acid precipitation.

5. Director of Research

The Acid Precipitation Act of 1980 designates the Administrator of NOAA as Director of Research for the Program. The Director assists the Task Force in overseeing the scientific integrity of research planning and the implementation of a balanced research program. The Director of Research works closely with the Executive Director and provides substantive input and guidance to Plan revisions and Annual Reports.

6. National Laboratory Consortium

The Act designates four National Laboratories as participants in the National Acid Precipitation Assessment Program. These laboratories--Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory--have formed a National Laboratory Consortium. The membership of the Consortium includes the Directors of the four laboratories, or their designees, who serve as members of the Interagency Task Force on Acid Precipitation. Annually, one of the Consortium members is elected chairperson, to represent the Consortium on the Research Coordination Council.

Facilities and staff at the four National Laboratories are being provided to perform acid precipitation related research, supported by the federal agencies and by private and state agencies as well. These facilities and staff also are available, as requested by the Joint Chairs, to assist the Task Force in the following functions:

- Establish a peer review procedure to ensure that research and development programs and their products are scientifically sound;

- Prepare plans to support the research required to complete the National Acid Precipitation Assessment Plan;

- Maintain an inventory of federally funded research projects;

- Provide a centralized data management function; and

- Assist the Task Force in other specialized tasks as requested.

The National Laboratory Consortium will meet periodically with the Task Force's Joint Chairs and the Research Coordination Council to review progress in the National Laboratory Consortium projects and to identify areas where the National Laboratories can make the most effective contribution to the research program.

C. Planning and Implementation

The Task Force will meet at least three times a year and as necessary to review the progress of the Program. A summer meeting will be held to review the activities of the Program, to determine future priorities, to plan for the Annual Report for the upcoming year, and to provide guidance for the preparation of the interagency budget analysis for the following fiscal year. A fall meeting will be convened to approve recommendations of an interagency budget. These budget recommendations are prepared for full Task Force consideration by the Research Coordination Council with input from the Task Groups. In the winter, a third meeting will be held to approve the Annual Report, to review the current year's program, and to plan for the next budget cycle. Other Task Force meetings will be held as necessary to ensure adequate oversight and administration of the National Program.

1. Budget Process

The role of the Task Force in planning the interagency budget for the National Program is a highly effective aspect of the federal effort. By working together through the Task Force, the agencies are establishing a research program that focuses on addressing national needs. The strong interagency planning process is designed to avoid proliferation of a set of loosely related projects, fill gaps, and eliminate undesirable duplication.

The Task Force sets the research goals, identifies the projects needed to meet those goals, and decides which agencies are best suited to conduct the necessary work. The result is a program of interlocking projects, with each agency contributing to specific aspects of the overall national effort.

The National Acid Precipitation Assessment Plan, supported by the annual interagency budget analyses, is the Task Force's key tool for managing the National Program. The budget recommendations for the various agencies' acid precipitation activities are reviewed by the Task Force as being part of a coherent multiagency program. A final interagency budget for the

Program is then submitted to OMB for review and then included in the President's budget request to Congress.

2. Annual Report

The Acid Precipitation Act of 1980 requires the Task Force to issue an Annual Report to the President and Congress describing the progress of the national research program. Annual Reports will analyze available information in order to assist in evaluating options regarding possible actions to alleviate acid rain and its effects. The Annual Report also serves as the vehicle for updating and revising the National Acid Precipitation Assessment Plan; as program results become available, the refocusing and redirecting of research and assessment efforts may become necessary. The Task Force's first Annual Report was issued in January 1982. This first report discusses the development of the management structure, National Plan, and initial implementation of the Program. Future reports will emphasize research results and their implications.

3. Annual Review Meeting

The Task Force holds an annual review meeting for program participants to assess research progress, to propose future work, and to assess the implications of existing information. The meeting involves Task Force members, researchers, program-level managers, and invited nonfederal participants. Research results and their implications are critically reviewed and future research plans are developed. The meeting assists participants in integrating information, sharing research results, and ensuring adequate program coordination.

4. Special Assessments

The Task Force will be issuing a series of special assessment documents as the Program's results become available. These Task Force documents will undergo rigorous peer review and their production will be coordinated by designated agencies. The Assessments and Policy Task Group will assist the Research Coordination Council in overseeing their production.

Special assessment and reports to be prepared in the first five years of the Program include:

	Preparation	Coordinating Agency
First Critical Assessment of Existing Scientific Information and Policy Implications	1982-1983	EPA
Deposition Monitoring Strategy	1982-1983	DOC
National Survey of Sensitive Lakes and Streams	1982-1983	EPA
Analysis of Past Trends in Acid Deposition	1983-1984	EPA
Terrestrial Inputs - Agricultural Systems	1983-1984	DOA

	Preparation	Coordinating Agency
Terrestrial Inputs - Non-agricultural Systems	1984-1985	DOA
State of the Art in Control Technology	1983-1984	EPA
Man-made Sources Assessment	1983-1984	DOE
Atmospheric Processes Analysis	1983-1984	NOAA
Damage Assessment for Materials and Cultural Resources	1984-1985	DOI
Natural Sources Assessment	1984-1985	NOAA
Second Critical Assessment Document	1985-1986	EPA

In subsequent years, reassessments will be made of these areas and new special assessments may be called for by the Task Force.

5. State and Private Sector Coordination

One of the major roles of the Task Force is to ensure coordination not only among federal programs, but also cooperation between these programs and those of the states, local governments, and the private sector. The development of this Plan itself serves as a coordination mechanism for communication among leaders of federal agencies and with others outside of the federal government. Each agency on the Task Force contributed to development of the Plan and has worked to ensure that its efforts support the total Program. Those outside of the federal government have taken advantage of opportunities provided to review and comment on the evolving National Plan (see Part I Section C).

Input from state and local governments, academic institutions, private sector groups, and individuals will continue to be sought and their suggestions will be considered in the planning and implementation of the Program. Nonfederal input will occur throughout the course of the Program through:

o Communication with the Task Groups (see section B.3 in this part);

o Participation in Task Force sponsored meetings and workshops;

o Peer review of research proposals and results; and

o Award of federal research support to groups with recognized capabilities in state and local governments, universities and the private sector.

Research scientists employed by states, universities, the private sector, or elsewhere will be involved in the design of and review of federal agency projects. It is hoped that federal researchers and managers also will be invited to assist nonfederal groups in the planning of their

activities. There is an existing model for cooperation in research design and peer review. Such a relationship is in effect between the acid rain programs of the U.S. Environmental Protection Agency (EPA) and the Electric Power Research Institute (EPRI). Under this relationship EPA, EPRI, university, and private contract scientists and managers plan and coordinate research.

The mechanism for the financial support to nonfederal research activities will continue as separate agency awards. Because the Task Force has no funds of its own to provide for research grants, it will assist in directing interested research scientists to the appropriate agencies responsible for activities in particular research categories.

6. International Activities

Transboundary air pollution is a subject of widespread international concern. The U.S. has been an active participant in both multilateral and bilateral fora in which the subject of long-range transport of air pollutants crossing international boundaries has been addressed. In 1979, the U.S., along with 35 other governments, signed the Long-Range Transboundary Air Pollution Convention under the auspices of the United Nations Economic Community for Europe (UN/ECE).

Since that time, the U.S. has been an active participant in the provisional implementation of the Convention. Indeed, in 1980, the U.S. deposited its Instrument of Acceptance with the Secretary General of the United Nations, becoming the ninth government to do so. In 1981, the U.S. assumed the chair of the Interim Executive Body created, in part, by the Convention and charged with overseeing its provisional implementation. There is an expectation that the necessary 24 governments will accept the terms of the Convention during 1982, thus bringing it into force.

Within the bilateral context, both the U.S. and Canada, who are signatories to the UN/ECE Long-Range Transboundary Air Pollution Convention, signed a Memorandum of Intent (MOI) in 1980 on transboundary air pollution. The MOI commits both governments to negotiate a transboundary air pollution agreement. To assist the governments in the negotiations, joint work groups were established to compile all relevant data on the long-range transport of air pollution, with major emphasis on acid precipitation. Interim actions have been taken by both governments and negotiations were opened in June 1981, as called for in the MOI. The final work group reports will be issued in 1982.

Domestically, the passage of the Acid Precipitation Act of 1980 (PL96-294) provided that the U.S. Interagency Task Force on Acid Precipitation cooperate with research performed by other governments. Currently, the U.S. provides data on acid precipitation to the UN/ECE under the provisions of the Convention. In association with Canada, acid deposition monitoring results and modeling data on the transport of acid precipitation precursors are exchanged and sometimes compiled and developed jointly. In addition, cooperative research projects on the effect of acid rain on the environment are underway with Canada.

The Task Force established an International Task Group (ITG) coordinated by the Department of State. The ITG will develop a framework for international cooperation on acid precipitation research programs. The ITG will make recommendations to the U.S. government on future activities of the U.S-Canada Research Consultative Group (RCG) established in 1978, which had been set aside following the 1980 MOI.

The ITG will assist the Joint Chairs and Research Coordination Council in tracking cooperation with Canadian and other nations research on acid rain. In addition, the ITG will prepare a compilation of current projects on acid precipitation research in other countries.

APPENDIX A

National Acid Precipitation Assessment Program
SUMMARY OF RESEARCH

Research Task (Coordinating Agency)	Priority	Duration (FY)	Agency Involvement* (Participating = 1) (Contributing = 2) DOA	EPA	NOAA	DOI	DOE	NSF	TVA	Other
A. Natural Sources (NOAA)										
1. Analysis & Assessment of Natural Sources of Acid Deposition	1	1981-1986		2	1	2	2	2		NASA
2. Case Studies of Neutralizing Materials in the Atmosphere	1	1981-1986	2	2	1		2	2	2	NASA
B. Man-Made Sources (DOE)										
1. Inventories of Current Emissions of Pollutants of Interest	1	1981-1990		1			1		2	
2. Developing Models for Emissions & Economic Analysis	1	1982-1990		1			1		2	
3. Baseline Emission Projections	1	1982-1990		1			1		2	
4. Analysis of Historic Emission Trends	2	1982-1986		1			1		2	
5. Detailed Analyses of Factors Affecting Emissions from Man-Made Sources	2	1983-1990		1			1		2	
C. Atmospheric Processes (NOAA)										
1. Research on Long-Range Transport & Dispersion	1	1982-1987		1	1	1	2	2	2	NASA
2. Determining Global & Regional Circulation of Acidic Materials	1	1980-1986		1	1		1	2	2	NASA

* Note - Agencies are considered participating in a task when they have resources specifically committed to it. Contributing agencies are ones conducting work that is relevant to the task but not directly involved as principals in the project.

SUMMARY OF NAPAP RESEARCH
(Continued)

Research Task (Coordinating Agency)	Priority	Duration (FY)	Agency Involvement (Participating = 1) (Contributing = 2) DOA	EPA	NOAA	DOI	DOE	NSF	TVA	Other
3. Investigating Chemical & Physical Transformations	1	1980-1990		1	1		1	2	1	NASA
4. Research on the Scavenging of Particles & Gases by Clouds	1	1980-1990		1	1		1	2		NASA
5. Improving Modeling Data Bases	3	1981-1985		2	2		1		2	
6. Improving Computer Simulation	1	1980-1985		1	1		1			
D. Deposition Monitoring (DOI)										
1. Continued Improvement & Evaluation of the Global Trends Networks (GTN)	1	1980-1990		1	1		2			
2. Further Development of National Trends Network (NTN)	1	1980-1990	1	1	1	1	2		1	
3. Developing Methods for Sampling Dry Measurements	1	1982-1987	2	1	1	2	1			
4. Expansion & Improvement of the Research Support Networks	1	1980-1990		1	1	1	1		2	
E. Aquatic Impacts (EPA)										
1. Monitoring National & Regional Water Quality	1	1982-1987	1	1		1			1	
2. Determining Factors that Control Lake Susceptibility	1	1980-1985	1	1		1		2	1	
3. Determining Relative Contribution of Nitric and Sulfuric Acid Inputs	1	1981-1986	1	1		1		2	1	
4. Evaluating the Significance of Mobilization of Toxic Metals	2	1982-1987	1	1		1	2		1	
5. Modeling Watershed Dose/Response Relationship	1	1981-1986	1	1		1	2	2	1	
6. Studying Acidification of Drinking-Water Sources	1	1980-1984		1		1				HHS
7. Monitoring Drinking-Water & Evaluating Treatment Methods	2	1983-1986		1		1				HHS

SUMMARY OF NAPAP RESEARCH
(Continued)

Research Task (Coordinating Agency)	Priority	Duration (FY)	Agency Involvement (Participating = 1) (Contributing = 2) DOA	EPA	NOAA	DOI	DOE	NSF	TVA	Other
8. Monitoring Regional Trends in Biological Effects	1	1980-1984		1		1			2	
9. Studying Watershed Productivity	1	1980-1990	1	1		1	2	2	1	
10. Identifying Vulnerable Growth Stages	1	1980-1985		1		1	2	2		
11. Studying Metal Contamination of Fish	2	1981-1983		2		1	2			
12. Analyzing Mitigation Strategies for Acidified Lakes	2	1982-1987	1	1		1			1	
F. Terrestrial Impacts (DOA)										
1. Studying Effects on Growth & Productivity of Forest Trees and Range Plants	1	1980-1990	1	1		1	2	2	1	
2. Identifying Vulnerable Growth Stages in Plants	2	1980-1990	1	2			2			
3. Investigating Effects on Metabolic Functions and Cellular Structures	1	1982-1992	1				2	2		
4. Analyzing Acid Deposition Induced Predisposition of Forest and Range Plants to Diseases and Insects	1	1982-1987	1	2						
5. Screening of Crop Species Sensitivity	1	1980-1985	1	1		1	2	2	1	
6. Developing Dose Response Relationships for Crop Growth and Yield	2	1982-1987	1	1			2		2	
7. Investigating Acid Deposition Induced Predispositions of Crops to Susceptibility to Diseases and Insects	3	1982-1987	1	1						

SUMMARY OF NAPAP RESEARCH
(Continued)

Research Task (Coordinating Agency)	Priority	Duration (FY)	Agency Involvement (Participating = 1) (Contributing = 2) DOA	EPA	NOAA	DOI	DOE	NSF	TVA	Other
8. Analyzing Metal Contamination of Crops	3	1982-1984	1				2			HHS
9. Characterizing Soil Vulnerability	1	1982-1985	1	1		1				
10. Studying Effects on the Ability of Soils to Support Vegetation	1	1980-1985	1	1			1	2	2	
11. Analyzing Soil Degradation Mechanisms & Mitigation Measures	3	1982-1987	1	1						
12. Analyzing the Buffering Capacity & Response of Watersheds to Acid Deposition	1	1981-1986	1	1		2	2	2	1	
G. Materials & Cultural Resources (DOI)										
1. Investigating Effects on Materials and Cultural Resources	1	1980-1985		1		1				GSA;DOD;NBS
2. Determining the Susceptibility of Cultural Resources	1	1982-1987		1		1				GSA;NBS
3. Estimating the Costs of Materials Damage	2	1984-1987		1		2	2			GSA;NBS
4. Research on Protective Coatings & Mitigative Treatments	3	1983-1986		1		1				GSA;DOD;NBS
I. Assessments & Policy Analysis (EPA)										
1. Compilation and evaluation of Costs and Performance of Potential Mitigation Measures	1	1982-1991	2	1		2	2			
2. Integrated Assessment of the Acid Precipitation Phenomenon and Potential Mitigation Measures	1	1982-1990	2	1		2	1			CEQ
3. Preparing Special Scientific and Policy Assessment Documents	1	1981-1990	1	1	1	1	1	2	2	DOS;HHS; NASA

SUMMARY OF NAPAP RESEARCH
(Continued)

Research Task (Coordinating Agency)	Priority	Duration (FY)	Agency Involvement (Participating = 1) (Contributing = 2) DOA	EPA	NOAA	DOI	DOE	NSF	TVA	Other
4. Program Information and Coordination Activities	1	Ongoing	1	1	1	1	1	1		CEQ(1)
5. Special Assessments and Analyses (Program's First 5-Years)	1	-- --	1	1	1	1	1	2	1	DOS;HHS; NASA;NBS
a. National Survey of Sensitive Lakes and Streams (EPA)		1982-1983								
b. Deposition Monitoring Strategy (DOI)		1982-1983								
c. Analysis of Trends in Acid Deposition (EPA)		1983-1984								
d. Atmospheric Processes Analysis (NOAA)		1983-1984								
e. Effects on Agricultural Terrestrial Systems (DOA)		1983-1984								
f. State of the Art in Control Technology (EPA)		1983-1984								
g. Man-made Sources Assessment (DOE)		1983-1984								
h. Effects on Nonagricultural Terrestrial Systems (DOA)		1984-1985								
i. Damage Assessment for Materials and Cultural Resources (DOI)		1984-1985								
j. Natural Sources Assessment (NOAA)		1984-1985								
k. Second Critical Assessment of Scientific Knowledge and Policy Implications (EPA)		1985-1986								

ACID PRECIPITATION ACT OF 1980
TITLE VII

STATEMENT OF FINDINGS AND PURPOSE

SEC. 702. (a) The Congress finds and declares that acid precipitation resulting from other than natural sources—

(1) could contribute to the increasing pollution of natural and man-made water systems;

(2) could adversely affect agricultural and forest crops;

(3) could adversely affect fish and wildlife and natural ecosystems generally;

(4) could contribute to corrosion of metals, wood, paint, and masonry used in construction and ornamentation of buildings and public monuments;

(5) could adversely affect public health and welfare; and

(6) could affect areas distant from sources and thus involve issues of national and international policy.

(b) The Congress declares that it is the purpose of this subtitle—

(1) to identify the causes and sources of acid precipitation,

(2) to evaluate the environmental, social, and economic effects of acid precipitation; and

(3) based on the results of the research program established by this subtitle and to the extent consistent with existing law, to take action to the extent necessary and practicable (A) to limit or eliminate the identified emissions which are sources of acid precipitation, and (B) to remedy or otherwise ameliorate the harmful effects which may result from acid precipitation.

(c) For purposes of this subtitle the term "acid precipitation" means the wet or dry deposition from the atmosphere of acid chemical compounds.

INTERAGENCY TASK FORCE; COMPREHENSIVE PROGRAM

SEC. 703. (a) There is hereby established a comprehensive ten-year program to carry out the provisions of this subtitle; and to implement this program there shall be formed an Acid Precipitation Task Force (hereinafter in this subtitle referred to as the "Task Force"), of which the Secretary of Agriculture, the Administrator of the Environmental Protection Agency, and the Administrator of the National Oceanic and Atmospheric Administration shall be joint chairmen. The remaining membership of the Task Force shall consist of—

(1) one representative each from the Department of the Interior, the Department of Health and Human Services, the Department of Commerce, the Department of Energy, the Department of State, the National Aeronautics and Space Administration, the Council on Environmental Quality, the National Science Foundation, and the Tennessee Valley Authority,

(2) the director of the Argonne National Laboratory, the director of the Brookhaven National Laboratory, the director of the Oak Ridge National Laboratory, and the director of the Pacific Northwest National Laboratory; and

(3) four additional members to be appointed by the President.

(b) The four National Laboratories (referred to in subsection (a)(2)) shall constitute a research management consortium having the responsibilities described in section 704(b)(13) as well as the general responsibilities required by their representation on the Task Force. In carrying out these responsibilities the consortium shall report to, and act pursuant to direction from, the joint chairmen of the Task Force.

(c) The Administrator of the National Oceanic and Atmospheric Administration shall serve as the director of the research program established by this subtitle.

SEC. 704. (a) The Task Force shall prepare a comprehensive research plan for the ten-year program (hereafter in this subtitle referred to as the "comprehensive plan"), setting forth a coordinated program (1) to identify the causes and effects of acid precipitation and (2) to identify actions to limit or ameliorate the harmful effects of acid precipitation.

(b) The comprehensive plan shall include programs for—

(1) identifying the sources of atmospheric emissions contributing to acid precipitation;

(2) establishing and operating a nationwide long-term monitoring network to detect and measure levels of acid precipitation;

(3) research in atmospheric physics and chemistry to facilitate understanding of the processes by which atmospheric emissions are transformed into acid precipitation;

(4) development and application of atmospheric transport models to enable prediction of long-range transport of substances causing acid precipitation;

(5) defining geographic areas of impact through deposition monitoring, identification of sensitive areas, and identification of areas at risk;

(6) broadening of impact data bases through collection of existing data on water and soil chemistry and through temporal trend analysis;

(7) development of dose-response functions with respect to soils, soil organisms, aquatic and amphibious organisms, crop plants, and forest plants;

(8) establishing and carrying out system studies with respect to plant physiology, aquatic ecosystems, soil chemistry systems, soil microbial systems, and forest ecosystems;

(9) economic assessments of (A) the environmental impacts caused by acid precipitation on crops, forests, fisheries, and recreational and aesthetic resources and structures, and (B) alternative technologies to remedy or otherwise ameliorate the harmful effects which may result from acid precipitation;

(10) documenting all current Federal activities related to research on acid precipitation and ensuring that such activities are coordinated in ways that prevent needless duplication and waste of financial and technical resources;

(11) effecting cooperation in acid precipitation research and development programs, ongoing and planned, with the affected and contributing States and with other sovereign nations having a commonality of interest;

(12) subject to subsection (f)(1), management by the Task Force of financial resources committed to Federal acid precipitation research and development;

(13) subject to subsection (f)(2), management of the technical aspects of Federal acid precipitation research and development programs, including but not limited to (A) the planning and management of research and development programs and projects, (B) the selection of contractors and grantees to carry out such programs and projects, and (C) the establishment of peer review procedures to assure the quality of research and development programs and their products; and

(14) analyzing the information available regarding acid precipitation in order to formulate and present periodic recommendations to the Congress and the appropriate agencies about actions to be taken by these bodies to alleviate acid precipitation and its effects.

(c) The comprehensive plan—

(1) shall be submitted in draft form to the Congress, and for public review, within six months after the date of the enactment of this Act;

(2) shall be available for public comment for a period of sixty days after its submission in draft form under paragraph (1);

(3) shall be submitted in final form, incorporating such needed revisions as arise from comments received during the review

period, to the President and the Congress within forty-five days after the close of the period allowed for comments on the draft comprehensive plan under paragraph (2); and

(4) shall constitute the basis on which requests for authorizations and appropriations are to be made for the nine fiscal years following the fiscal year in which the comprehensive plan is submitted in final form under paragraph (3).

(d) The Task Force shall convene as necessary, but no less than twice during each fiscal year of the ten-year period covered by the comprehensive plan.

(e) The Task Force shall submit to the President and the Congress by January 15 of each year an annual report which shall detail the progress of the research program under this subtitle and which shall contain such recommendations as are developed under subsection (b)(14).

(f)(1) Subsection (b)(12) shall not be construed as modifying, or as authorizing the Task Force or the comprehensive plan to modify, any provision of an appropriation Act (or any other provision of law relating to the use of appropriated funds) which specifies (A) the department or agency to which funds are appropriated, or (B) the obligations of such department or agency with respect to the use of such funds.

(2) Subsection (b)(13) shall not be construed as modifying, or as authorizing the Task Force or the comprehensive plan to modify, any provision of law (relating to or involving a department or agency) which specifies (A) procurement practices for the selection, award, or management of contracts or grants by such department or agency, or (B) program activities, limitations, obligations, or responsibilities of such department or agency.

IMPLEMENTATION OF COMPREHENSIVE PLAN

SEC. 705. (a) The comprehensive plan shall be carried out during the nine fiscal years following the fiscal year in which the comprehensive plan is submitted in its final form under section 704(c)(3); and—

(1) shall be carried out in accord with, and meet the program objectives specified in, paragraphs (1) through (11) of section 704(b);

(2) shall be managed in accord with paragraphs (12) through (14) of such section; and

(3) shall be funded by annual appropriations, subject to annual authorizations which shall be made for each fiscal year of the program (as provided in section 706) after the submission of the Task Force progress report which under section 704(e) is required to be submitted by January 15 of the calendar year in which such fiscal year begins.

(b) Nothing in this subtitle shall be deemed to grant any new regulatory authority or to limit, expand, or otherwise modify any regulatory authority under existing law, or to establish new criteria, standards, or requirements for regulation under existing law.

AUTHORIZATION OF APPROPRIATIONS

SEC. 706. (a) For the purpose of establishing the Task Force and developing the comprehensive plan under section 704 there is authorized to be appropriated to the National Oceanic and Atmospheric Administration for fiscal year 1981 the sum of $5,000,000, to remain available until expended.

(b) Authorizations of appropriations for the nine fiscal years following the fiscal year in which the comprehensive plan is submitted in final form under section 704(c)(3), for purposes of carrying out the comprehensive ten-year program established by section 703(a) and implementing the comprehensive plan under sections 704 and 705, shall be provided on an annual basis in authorization Acts hereafter enacted; but the total sum of dollars authorized for such purposes for such nine fiscal years shall not exceed $45,000,000 except as may be specifically provided by reference to this paragraph in the authorization Acts involved.

APPENDIX C

List of Acronyms

AL	Aeronomy Laboratory (NOAA)
ARCC	Acid Rain Coordinating Committee (defunct)
ARL	Air Resources Lab (NOAA)
ARS	Agricultural Research Service (DOA)
BLM	Bureau of Land Management (DOI)
BM	Bureau of Mines (DOI)
BUREC	Bureau of Reclamation (DOI)
BWCA	Boundary Water Canoe Area
CANSAP	Canadian Sampling Network for Acid Precipitation
CEQ	Council on Environmental Quality
CSRS	Cooperative State Research Service (DOA)
DOA	Department of Agriculture
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
EEFF	Electrostatically-Enhanced Fabric Filtration
ENAMAP	Eastern North America Model of Air Pollutants
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Agency (defunct)
ESRL	Environmental Sciences Research Laboratory (EPA)
FGD	Flue Gas Desulfurization
FS	Forest Service (DOA)
FWS	Fish and Wildlife Service (DOI)
GTN	Global Trends Network
HHS	Department of Health and Human Services
ILWAS	Integrated Lake Watershed Acidification Study
LIMB	Limestone Injection/Multistage Burner
LRTAP	Long-Range Transboundary Air Pollution
MAP3S	Multi-State Atmospheric Power Production Pollution Study
MOI	Memorandum of Intent, U.S.-Canada
NADP	National Atmospheric Deposition Program
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBS	National Bureau of Standards (DOC)
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration (DOC)
NPS	National Park Service (DOI)
NSF	National Science Foundation
NSPS	New Source Performance Standards
NTN	National Trends Network
NWS	National Weather Service (NOAA)
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSM	Office of Surface Mining (DOI)
PHS	Public Health Service (HHS)
R&D	Research and Development
RSN	Research Support Network

SAES	State Agricultural Experiment Station (DOA)
SCS	Soil Conservation Service (DOA)
SURE	Sulfate Regional Experiment (EPRI)
TVA	Tennessee Valley Authority
USGS	United States Geological Survey (DOI)
VOC	Volatile Organic Compounds
WMO	World Meteorological Organization

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